Energy process' sequence control system using Metso DNA FbCAD & Sequence CAD

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Description

The thesis was assigned by JAMK University of Applied Sciences to be part of a resource material for automation and energy technology students.

The objective of the thesis was two-fold. The first objective was to prepare a sequence control program for an energy process system, in order to control modules of the energy process sequentially. The task was implemented using Function Block CAD, Sequence CAD and DNAuser-program of Metso DNA automation tools.

The other objective was to read on HMI Control Panel displayed data of the steam generator from a process field into a control room using Metso DNA automation tools. Function Block CAD and DNAuser program were used to link with the available data of the steam generator from a control room. The steam generator is the only module of the energy process not controlled by Metso DNA automation system, but by Siemens S7 300 programmable logic controller (PLC).

Henceforth, by applying the Metso DNA automation sequence control program energy process modules and most components of the energy process system can be combined and operated together in such a way that the overall process operates automatically in a preset sequence order. Furthermore, variable information and data of the steam generator are easily accessible from the control room.

Keywords (subjects)

Metso DNA automation, Function Block CAD, Sequence CAD, JAMK University of Applied Sciences

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Opinnäytetyön nimi
Energiatekniikan prosessin sekvenssiohjaus järjestelmä käyttäen Metso DNA:in FbCAD - ja SeqCAD -suunnittelutyökaluja

Tutkinto-ohjelma
Automaatiotekniikka

Työn ohjaaja(t)
Kuisma, Ari

Toimeksiantaja(t)
Jyväskylän ammattikorkeakoulu

Tiivistelmä

Opinnäytetyön toimeksiantaja oli Jyväskylän ammattikorkeakoulu.

Opinnäytetyön päätavoitteena oli valmistaa energiatekniikan prosessijärjestelmälle sekvenssiohjausohjelma, joka ohjaa energiaprosessin moduulit sekvenssijärjestyksessä. Opinnäytetyö toteutettiin käyttäen Metso DNA:n automaatiosuunnittelutyökaluja FbCAD (toimilohkokaaviot), SeqCAD (sekvenssikaaviot) ja DNAuser.

Toinen tavoite oli lukea höyrystimen HMI-paneelilla näytettyä dataa. Tiedot luetaan prosessin alueelta valvomoon käyttäen Metso DNA:n automaatiosuunnittelutyökaluja. FbCAD- ja DNAuser-ohjelmia käytettiin yhdistämään höyrystimeltä saatavana olevia tietoja valvomoon. Höyrygeneraattori on ainoa energiatekniikan prosessin moduuli, jota ei ohjata Metso DNA -automaatiojärjestelmällä, vaan Siemens S7 300- ohjelmoitavalla logiikalla (PLC).

Soveltamalla Metso DNA -automaatiosekvenssiohjausohjelmaa voidaan yhdistää ja käyttää yhdessä useamman prosessin laitteita ja energiatekniikan moduuleita, niin että kokonaisprosessi toimii automaattisesti esiasetetussa järjestyksessä. Lisäksi höyrystimien muuttuvat tiedot ja data ovat helposti saatavilla valvomosta.

Opinnäytetyössä valmistettua järjestelmää on mahdollista käyttää automaatio- ja energiatekniikan opiskelijoiden laboratoriotöissä.

Avainsanat (asiasanat)

Metso DNA automation, Function Block CAD, Sequence CAD, Jyväskylän ammattikorkeakoulu

Contents

Symbols

ALS	Alarm Server
AS−I	Actuator Sensor Interface
BU	Backup server Manager
CPU	Central Process Unit
CAD	Computer Aided Design
EAS	Engineering and Maintenance Activity Server
EAC	Engineering and Maintenance Activity Client
FCIN	Function control input
GSD file	General Station Description
I/O	Input/Output
MetsoDNA	Dynamic Network of Applications
PLC	Programmable Logic Controller
PROFIBUS DP	Process Field Bus Distributed Peripherals
PROFIBUS PA	Process Field Bus Process Automation
PROFIBUS OLM	Optical Link Modules
OPS	Operator Server
PCS	Process Control Server

Figures

Tables

1 Introduction

The energy technology laboratory at JAMK University of Applied Sciences provides a learning environment for students with practical training and technical skills of PLC programming, HMI (human machine interface) programming, process system control, and other important plant tasks.

The energy process system in the energy technology laboratory is composed of four different modules, namely, pumping module, pressurized-water module, cooling module and steam generator. When these modules are connected together they build up a single process. Each of these modules can run individually and meanwhile, can collaborate with each other to operate in a sequential order as needed by an operator.

The main purpose of this thesis was to design Metso DNA automation controlling system for energy process system, with the exception of the steam module so that all modules can operate in a sequence order. This thesis does not include preparing function block diagrams from the very beginning for those modules, for they have been already done before. Yet by reviewing and updating already existing function block diagrams based on them have been prepared anew.

Another purpose of this thesis was to prepare function block diagrams and DNAuse process picture for steam generator's field devices so that the statuses and data of field devices can be read from a control room using Metso DNA automation system. All modules of the energy process system can be controlled by Metso DNA automation system from a control room, however the steam generator is controlled and monitored from the HMI Control Panel in the process field with Siemens S7-300 PLC.

2 Energy Technology Laboratory's Energy process System

As it is mentioned already in the introduction, the energy process in the energy technology laboratory has four modules, which can operate individually or as a single process according to the operator's wish. As a result the energy process can be run in many different patterns according to operations and control loops needed. Each module possesses more than one loop to manipulate the process variables to meet the end result needed and to control pressure, temperature and water flow.

The role of the devices and the process description details of each module are stated widely in a functional description file attached which is translated from Finnish into English as part of the thesis. Therefore, the detailed description of devices is omitted in this thesis intentionally except the following general, most important, and short descriptions of the modules to give a general understanding about the energy process.

2.1 Pumping Module

The task of the pumping module is to ensure sufficient additional water supply to pressurized-water module loop and further to steam water module during overall process running (Energiatekniikan prosessin toimintakuvaus, 5).

2.2 Pressurized-water Module

The function of pressurized-water module is to stabilize the energy process system by ensuring water supply in case a failure happens in the pumping-water loop even for a short period of time. Furthermore, water is pressurized in this module before it is injected into a steam water loop. (ibid., 18.) The task of pressurizing water to the required set-point is performed by two pressure regulator valves mounted on the pressure tank.

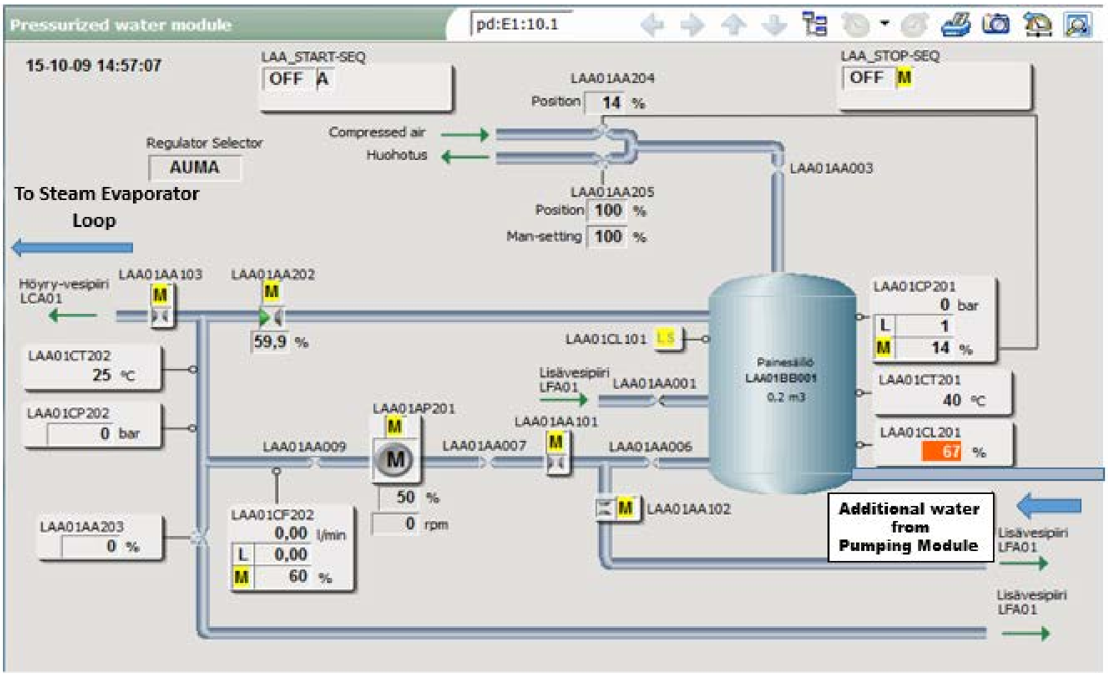

Figure 1. Pressurized-water module process picture (Pressurized-water module)

2.3 Cooling Module and Steam Generator

The cooling module serves as a load for the steam generator. As illustrated in Figure 2, cooling water circulation loop designated with the letter A, on the right side of the cooling water tank, serves as a load for the steam generator. The cooling water is pumped to heat exchanger with pump AP201 from the cooling tank, and the steam leaving the steam generator moves into the heat exchanger. When the steam transfers its heat to the cooling water, it condenses and turns into water. The condensate will be discharged downwards freely from the heat exchanger to steam trap HAD01AB003. The condensate can be reused as feed water for the steam generator to repeat the process after it has been conducted into the feed-water tank.

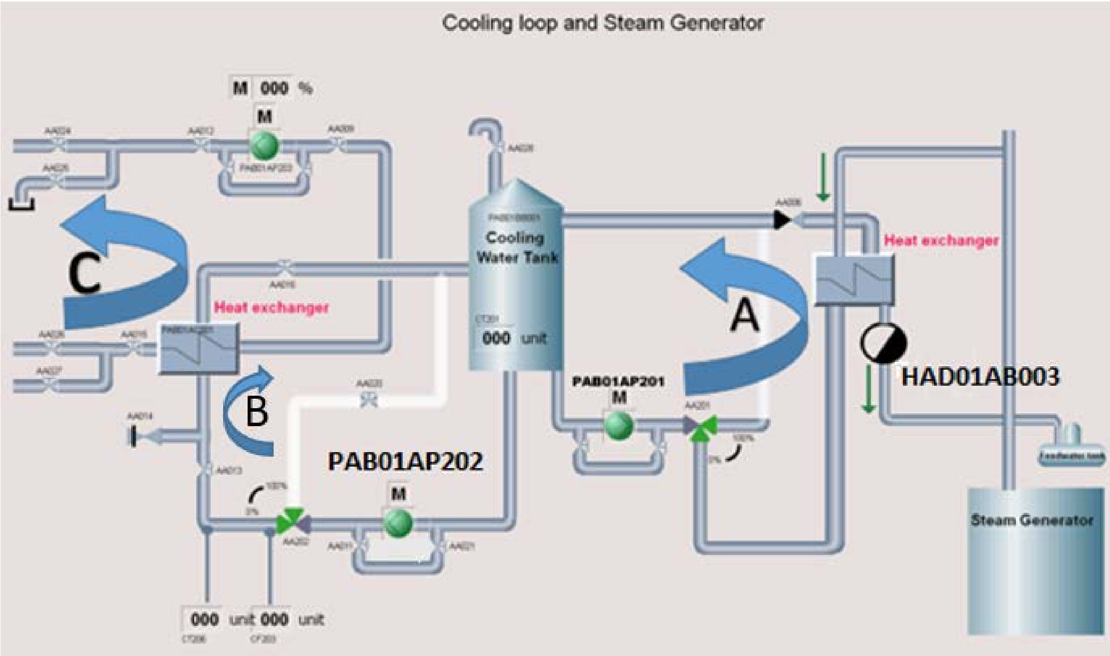

Figure 2. Steam generator and cooling water loop.

The cold water from the cooling water tank does not come in contact with steam water from the steam generator. They are physically isolated since the heat exchanger has two completely separated parts. It is important to know that: the two fluid systems cooling water from the cooling tank, and hard steam water from evaporator remain in their own separate loop and never mix. Therefore, there is no removal or loss of water from the loops, except that occurs due to steam leakage.

The water inside cooling water tank can be cooled by circulating it through the heat exchanger, as shown in Figure 2 above, on the left side of the cooling tank. The heat removed from the cooling water will be further transferred to network water pipeline and then to drainage via loop designated with the letter C.

Generally, as described above in brief, the steam generator and the cooling module play the role of heating and cooling water. The steam generator is designed to represent a district heating center that supplies heating for a residence and the heat exchanger on the right side of the tank in the above figure represents a house heating radiator.

The cooling module is equipped with two pumps to regulate the temperature of cooling water. The amount of heat that is transferred from steam to cooling water can be regulated by varying the speed of pump PAB01AP201. The faster the cooling water is pumped through the heat exchanger, the shorter the time is for cooling water to pick up the heat from the steam.

2.4 Overall Process

The term overall process is used to describe the collaborated operation of all four modules mentioned above. When these modules operate in combination, they represent a district heating network.

With the aid of two pumps connected in series, extra water is pumped from the first part of the overall process, or pumping module into the pressurized-water module. After being pressurized the extra water is dosed into the evaporator system when there is a need. Water dosing power comes by keeping pump LAA01AP201 (Figure 1) running continuously or from the pressurized-water tank. (ibid. , 5.) The third and fourth parts of the overall process, which has the role of heating and cooling water, have already been described in the former section.

3 Metso DNA automation system description

3.1 Metso DNA system

Metso DNA automation system of energy technology laboratory enables a distributed control system wherein control I/O units are distributed throughout the process system in the field. Field devices are connected to the system by PROFIBUS DP, PA and AS-Interface. To local control I/O units, field devices are connected either by parallel connection or a single multi drop cable. For example, as it can be seen in Figure 5 (page 14), all on/off valves of pressurized water module are connected to PHOENIX CONTACT I/O module by parallel connections, on the other hand, the frequencey converter of pump LAA01AP201 is connected by a single multi drop cable or PROFIBUS DP cable directly through DP coupler to Metso DNA ACN CS process controller.

All local control I/O units in the energy process field are attached with PROFIBUS DP cables to Metso DNA ACN CS controllers, which are located in the laboratory's control room cabinet. The controllers are in turn connected via Ethernet to engineering and operator server.

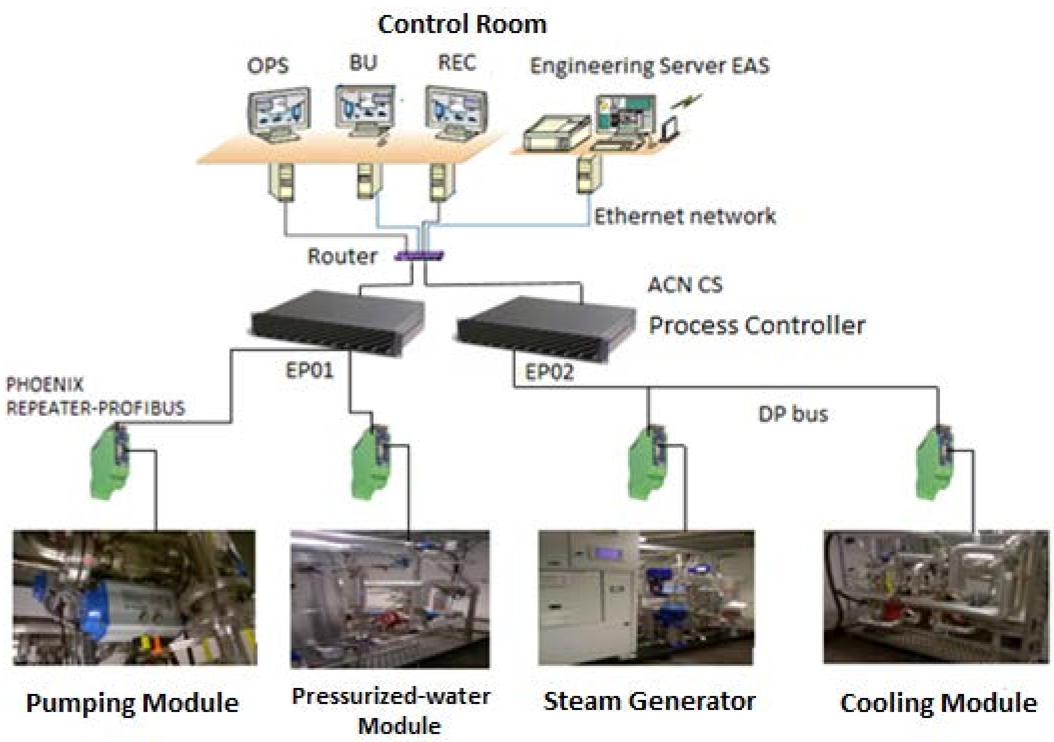

Figure 3. Metso DNA system of the energy process in the energy technology laboratory

3.2 Description of Metso DNA automation system server

Metso DNA system functions are distributed over different stations, which are connected to each other with an Ethernet-based bus system for communicating with each other (Rakurs industrial automation, 2015). The automation system consists of the following servers.

Engineering Server (EAS)

An engineering server is a server where the repository and workspaces are located. The engineering server node (EAS) together with the Engineering Workstation (EAC) node forms the backbone of the Metso DNA engineering environment. Engineering workstation (EAC) is a network station of engineering server, which includes engineering tools but does not include repository or workspaces. The engineering repository and the tools are installed on Windows workstation. (Function Block CAD – Manual. 2011.3)

All engineering data are stored in the engineering database located in the engineering server. A function block diagram, sequence diagram and picture design for control room are saved in the engineering database located in the engineering server (EAS), from where they can be reopened to be viewed or modified. All engineering data and documents stored in the engineering database can be reviewed, structured and maintained with DNA Explorer. (ibid., 1.)

From the engineering server, engineering data is transferred to the Metso DNA runtime environment. The entire Metso DNA system's configuration is handled from the Engineering Server, which contains a database for all control applications and field device parameters. (ibid., 3-13.)

Operator Server (OPS)

On the Operator Server, runs a human machine interface program, providing information about the processing system for a process operator to monitor the processing system from a control room (Valmet_DNA_peruskurssi, 6).

Alarm Server (ALS)

ALS collects data regarding process alarms and events, and forwards them to control room, where the alarms and events are displayed (ibid. , 6.)

Process Control Server (PCS)

PCS measures, controls, regulates and generates alarms. (ibid. ,6.) There are two process control servers in the Metso DNA control cabinet of energy technology laboratory, labeled EP01 and EP02. Pumping module and pressurized-water module are controlled by EP01. EP02 is used to control the cooling module and to read data from the steam generator.

Figure 4. Metso DNA ACN CS process controller installed in the energy laboratory cabinet (Products and solutions 2011, 24.)

Backup server Manager (BU)

All applications and their modifications are downloaded to system's different servers through the backup server. (Valmet_DNA_peruskurssi, 6.)

Diagnostic Server (DIA)

DIA is used for testing of the application, analyzing the operation of Metso DNA troubleshooting, and system maintenance. (Metso DNA Engineering - Debugger Manual. 2011.9)

3.3 Fieldbus

In the energy technology laboratory, the demand of the bunch (point to point or parallel) connections between energy process field devices and Metso DNA automation controlling system is eliminated by using serial transmission of data through a single line of Fieldbus. Some of the field devices are connected to local controllers with Fieldbus and others are connected directly with point to point connections to I/O modules. Metso DNA automation controlling system of the energy process communicates with field devices via PROFIBUS DP, PROFIBUS PA, and AS-Interface cable as can be seen in Figure 5 below.

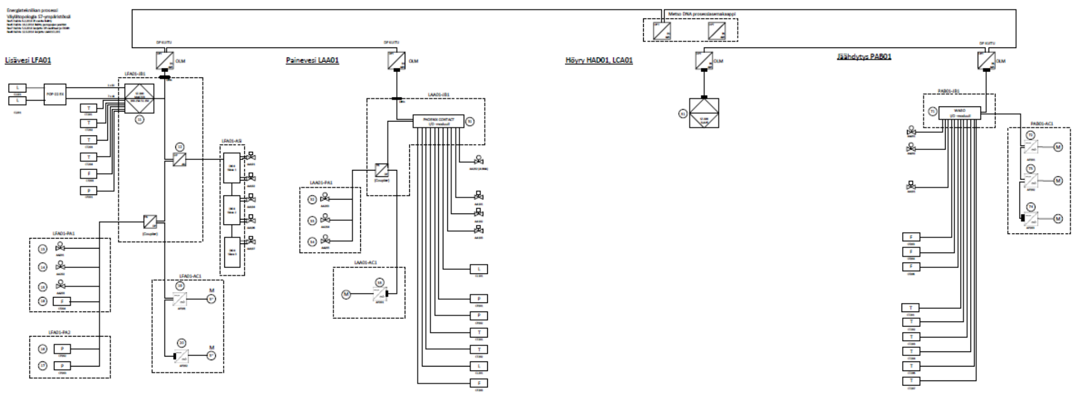

Figure 5. Energy process topology of Energy technology laboratory (Energy technology laboratory)

PROFIBUS-DP (Distributed Peripherals) - PROFIBUS stands for process fieldbus and DP stands for decentralized peripherals, used to describe distributed I/O field devices connected by means of a fast serial data link with a central controller. Metso DNA ACN CS is the central controller of the energy process system of the energy technology laboratory. PROFIBUS DP is capable of transmitting thousands of I/O data in a few milliseconds, and its speed can be varied from 9.6Kbps to 12Mbps. (PROFIBUS and its types – PLC Manual)

PROFIBUS DP bus segments are linked together in series using the RS-485 repeater to strength the data signals as it is seen from the energy process topology of energy technology laboratory in Figure 5.

Through fiber optic cables the Metso DNA I/O modules are connected in linear with local I/O modules using the PROFIBUS OLM (Optical Link Modules). PROFIBUS optical link modules are used to convert electrical PROFIBUS interfaces (RS-485) into optical PROFIBUS interfaces and backward (SIMATIC NET PROFIBUS).

The physical link DP/PA coupler is used between PROFIBUS DP and PROFIBUS PA in pumping-water module and pressurized-water module. PROFIBUS PA is slower than PROFIBUS DP, however, the message format is same as in PROFIBUS DP. PROFIBUS PA extends PROFIBUS DP with mostly safe transmission of data, especially for measuring devices where there is a hazard of explosion (due to pressure or temperature) and for valves which need more safety in chemical industries. (PROFIBUS and its types – PLC Manual) However, the main function of PROFIBUS PA in the energy technology laboratory of energy process system is to supply power to the connected field devices and transferring data.

AS−Interface -The AS−Interface in Metso DNA ACN CR is connected using a DP/AS−Interface Gateway unit, hence instead of being directly connected to a master AS−I bus is connected to the DP bus. The connection of AS-interface is counted as a DP interface to Metso DNA ACN CS (AS-i Field Bus - Manual). All On/Off valves of the pumping module are connected using AS-Interface to the DP bus as the slave devices in order to transfer the binary signals as seen in Figure 5 above.

4 Metso DNA Engineering Tools

4.1 DNA Explorer

DNA Explorer is an engineering tool that is used for application engineering and maintenance. It is the core of Metso DNA engineering and maintenance, which offers one to use configuration and maintenance application for all control functions. DNA Explorer enables modifying of multiple loops at the same time in a sheet format and with powerful mass operation tools. (Function Block CAD Manual). It also enables remote engineering.

4.2 Function Block CAD

Function Block CAD is a Metso DNA computer aided designing tool that is used in designing function block diagrams for process control loops, sequences, and interface applications. Function block diagram is drawn for each field device, sensor, and actuator that are remotely accessible by an operator.

Function block diagrams are saved in the engineering server's repository from where they can be reopened, before they are loaded into runtime environment for the purpose of controlling the process. (Function Block CAD – Manual. 2011, 15.)

Function Block CAD can be started from the start menu. It is also possible to create a new function block diagram in the DNA Explorer by selecting the Object->Create->Function Block Diagram command of the DNA Explorer.

The following diagram shows a function block diagram and parts it consists.

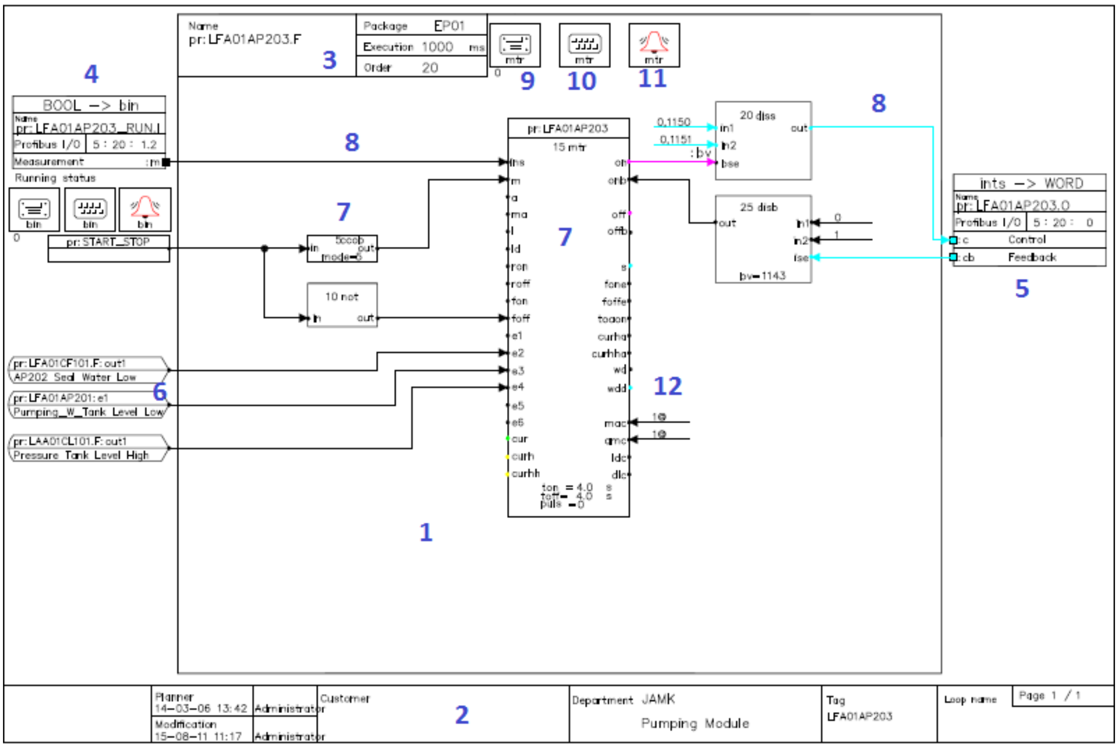

Figure 6. Function block CAD diagram

Function Block CAD's parts are as follows:

1. Area for connections and configuration of function blocks; 2. Date, Names of document, revisions etc.; 3. Function module name, Process controller, order, execution cycle; 4. The external input I/O connection, FBC slot place, etc.; 5. External Output I/O connection e.g. physical I/O; 6. Connections from external modules, which can be in the same process or another one e.g., remote set point; 7. Function block of a device for the configuration of the control function; 8. The connection between I/O and function blocks; 9. The tag function; 10. The operation function; 11. The event function; 12. Synchronize command (@) used for updating information from the runtime environment to the engineering environment. (Metso DNA Engineering - Brochure.2011, 4)

The function block diagram consists of configuration functions such as continuous controls, I/O functions, and operations. The configuration functions of the function block diagrams, function blocks, ports, etc. can be connected to each other with connection lines. (Function Block CAD – Manual. 2011, 11-13.)

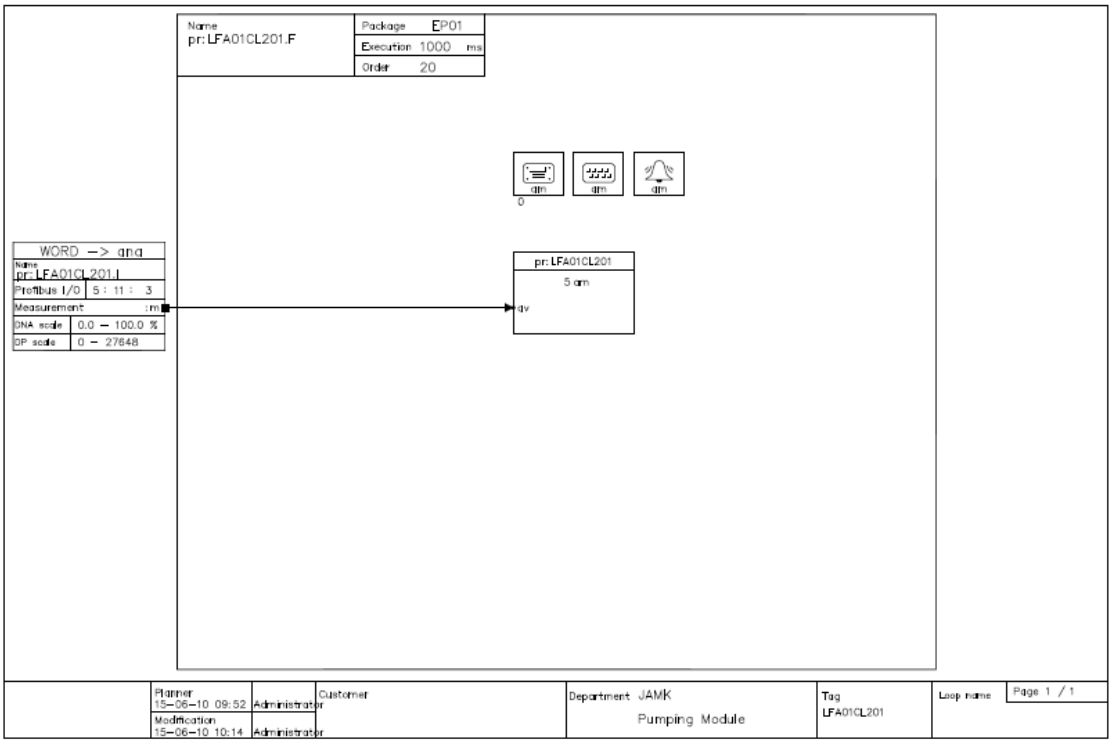

Figure 7. Function block diagram of tank level measurement

For example, as seen from the above function block diagram in figure 7, the output of the level indicator of the cooling water tank I/O functions can be connected to the measurement input of the controller function block with a connection line. As a result, when a function block diagram is loaded in the runtime environment, the operator can follow the measured tank level from a control room. The I/O functions of the PROFIBUS input Fieldbus from the level indicator used above is connected to PROFIBUS word ->ana module.

Based on the function block diagram designed for each field device, the engineering tools create the application, which can be loaded from the engineering database server to the runtime environment for process control. Only the configuration functions are transferred, but not comments to the runtime environment during loading. Each configuration function of the function block is directed to be run in an application server particularly specified for it. For example, continuous control is always specified to be run in a Process Control Server, event function in an Alarm and

Event Server, and operation function in an Operation Server. (Function Block CAD – Manual. 2011, 13.)

A function block diagram is tested for its reliability, when it is completed using the Check command before saved in the engineering server (EAS) workspace or repository. A function block diagram can be loaded into real runtime environment with the download command of a Function Block CAD or from a DNA Explorer by right clicking and selecting ‘Download to’ command, as shown in Figure 8 below. After deselecting ‘Accept to backup’, finally by pressing ‘OK’ button the file can be loaded into a runtime environment. (ibid., 13-29.)

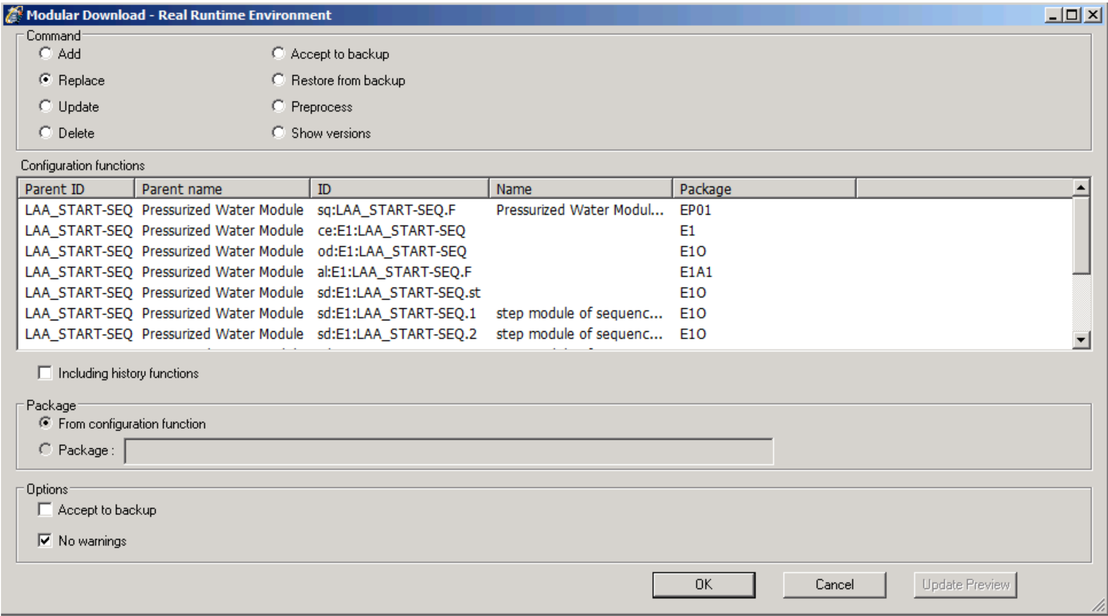

Figure 8. Function block diagram loading to process server

4.3 Sequence CAD

Sequence CAD is a Metso DNA engineering tool that is used in designing sequence diagrams. A sequence control program is a program made to automate sequential control actions chronologically. The serial parts of a sequence are called steps. Each particular step contains actions that can be executed at the same time, but steadily beginning from the top all the way down (Sequence CAD – Manual. 2011, 13).

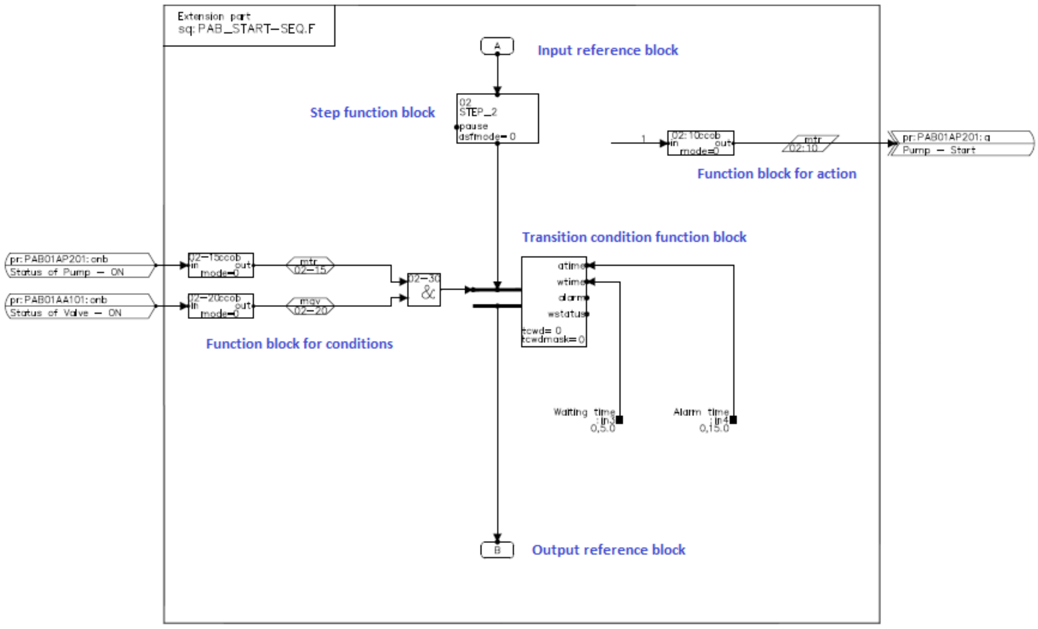

Figure 9. A sequence step of the pumping module

Every sequence diagram starts with a step function block, whereby a step's order number is marked, as can be seen in figure 9 above.

The transition from one step to the next takes place when the transition conditions are fulfilled. (ibid., 13.) For example, the figure above presents a sequence diagram of pumping module with step 2, whereby the transition to the next step (step 3) takes place when the valve becomes open and the pump starts.

The actions to be executed in a step are illustrated in Figure 9 above on the right upper side of the step diagram as a function block for actions, and conditions to be carried out on the left side of the step diagram as a function block for conditions. During execution of sequences, only one step can be active at a time progressively. (ibid., 4.)

Reference block is required after the transition condition block to refer the existing sequence step to the following sequence step. Reference block's name determines to what input reference block the existing sequence step is referred. For example, the input reference block name of the next sequence step (step 3) must have the same name as the output reference block name (B) of the present sequence step as shown in the figure above.

Sequence CAD has a handful of command tools that can automate tasks by enabling mass editing for sequence diagrams all at once, such as Tedit-Command to edit several texts at the same time, Renum - Command to automatically renumber function blocks of a step, Gedit-Command and etc. (ibid. , 77-79). More details of these command tools and other can be accessed from Metso DNA Sequence CAD manual.

A sequence is divided into two main levels in relation to data type at a process server.

- Sequence management level – which contains ‘seqmng’ data type.
- Linear subsequence – which contains ‘lseqmng’ data type.

The sequence management data structure ‘seqmng’ links to entire sequence control, and the linear subsequence data structure ‘lseqmng’ links to data that contains individual subsequences. Sequence data type ‘seqmng’ triggers subsequence data type ‘lseqmng’ hierarchically when the execution of an entire sequence is needed. (ibid. , 18-19.)

Sequence management data structure ‘seqmng’ is represented as an interface port with the name ‘seqadmin’ during the sequence control’s representation. (ibid. , 19.)

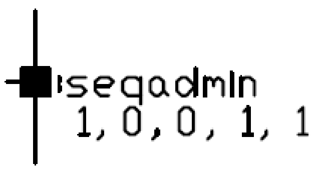

Figure 10. Input Interface port ‘seqadmin’

Linear subsequence management data structure ‘lseqmng’ gives the user an access to read/control data of individual subsequences. The ‘lseqmng’ data structure is represented as an interface port with the name ‘subadmin’ as shown in Figure 11 below. (ibid. , 23.)

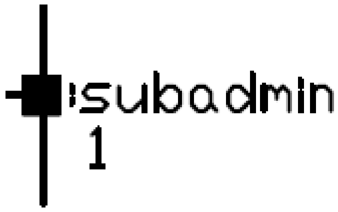

Figure 11. Input interface port ‘subadmin’

4.4 Fieldbus Configuration

Fieldbus configuration is performed using SST PROFIBUS Configuration tool.

First, PROFIBUS DP cables from energy process have to be connected to the bus cards of process controls. DP cables of Pumping module and Pressurized-water module are connected to EP01 process control’s bus card as well as Steam generator and the cooling module are connected to EP02 process control’s bus card.

Siemens s7-300 PLC of steam generator’s PROFIBUS GSD files required to configure the DP link with DP master downloaded from Siemens website to computer’s C disk of PBC/GSD files and further to master card EP02_m5.pbc using SST PROFIBUS Configuration tool. The GSD files were added to the configuration tool library by opening library and add.

Eleven slave devices of Siemens S7 300 PLC were added to the configuration. The configuration is saved to PBC server by opening: Edit->Export binary.

Then after SST PROFIBUS, Configuration window is closed.

Next step occurs by opening DNA Explorer window and further Package Hierarchy: by right clicking the required configuration packet, EP01-m5-pbc for Siemens S7 300 importing is done.

The GSD files of the other modules were downloaded earlier, however, their addresses required modification due to the change in the master card addresses. After the master card addresses were modified, the GSD files of the devices were downloaded using DNA Explorer by right clicking DNA Explorer and opening Package Hierarchy.

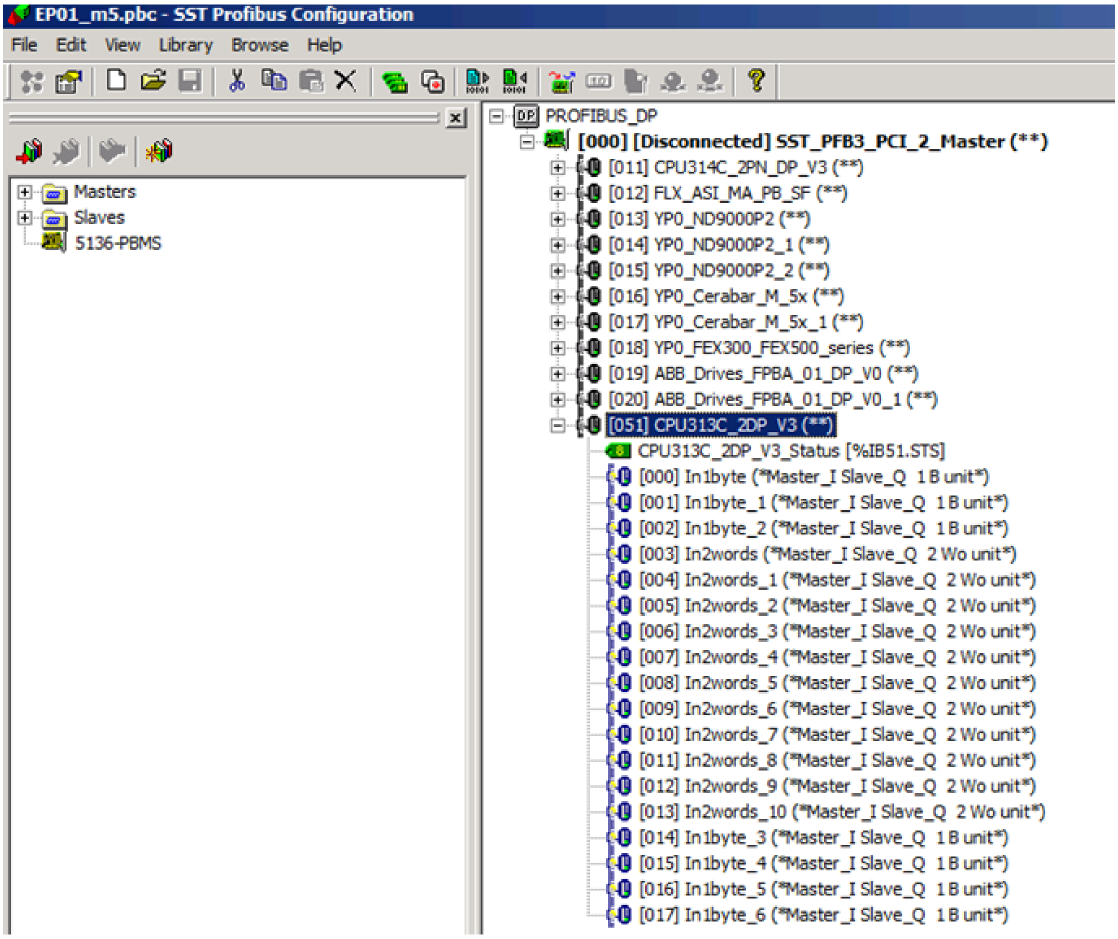

Figure 12. Slave devices of Siemens S7 300 PLC added to the configuration

4.5 Control Room

The control room's process picture provides an operator with continuous and instantaneous variable values of the energy process such as tank level, temperature, pressure, and flow, as well as process data and all process events. An operator can control and supervise the overall process of each and every modules from a DNAuser interface workstation or control room. The process picture of the control room which illustrates pumping-water module's instantaneous process values is displayed in Figure 13.

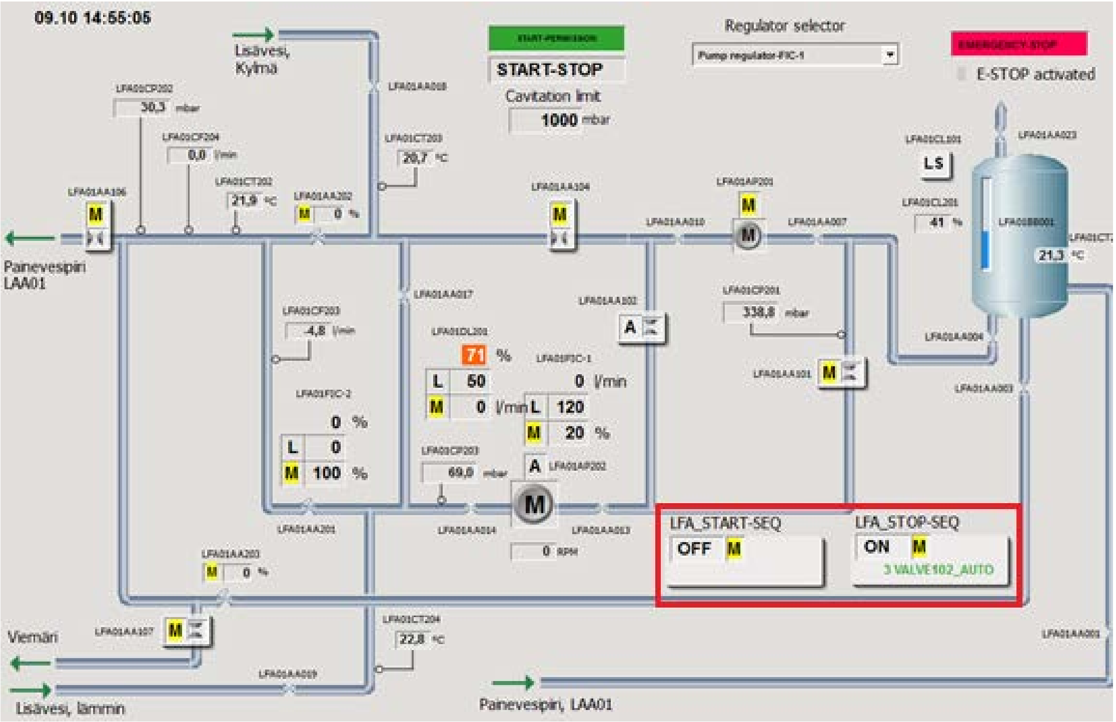

Figure 13. Pumping module's instantaneous process value (Energy technology laboratory)

5 Basic and Detail Designing

Sequence control of the energy process system in the energy technology laboratory is implemented by creating the function block diagrams, sequence diagrams and process pictures of the field devices.

5.1 FbCAD Basic Designing

First of all, the Function block diagram is prepared for each field device according to the functions stated in the functional description. The function block diagrams are prepared so that they can be controlled from a Sequence CAD. The function block input ports such as 'm', 'a', and 'ma' are left unconnected at Function Block CADs, as shown in Figure 14 below, for they will be activated from a Sequence CAD. However, other input ports of a function block, such as 'son' (valve opening limit), 'soff' (valve closing limit), 'soff' and 'e1' (device protections and safety switches) are connected at Function Block CADs to the external input I/O connections. It is not important to connect all input ports of a function block if there is no more function needed to be carried out.

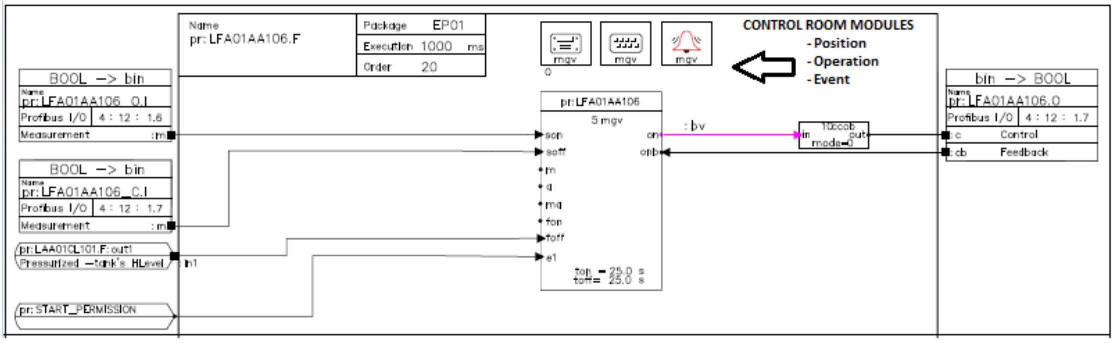

Figure 14. Function block diagram of LFA01AA106 On/Off valve

Three components of the control room modules, namely, position, operation and event functions are applied at the function block diagram in order to display the devices or modules in the control room as shown in the figure above.

5.2 Functional Description of FbCAD

Functional descriptions of On/Off valve from pumping module and temperature sensor of the pressurized-water tank are given below for designing a function block diagram. This is just to illustrate as a sample of how other all field devices of the function block diagrams are prepared.

1. <u>LFA01AA106-On/Off valve from pumping module </u>(reference to Appendix 1)

- Input module name for open limit of valve– pr: LFA01AA106_O.I
- I/O function for reading open limit of valve – will be selected from PROFIBUS submenu ‘PROFIBUS input’ and ‘BOOL → bin’
- I/O function address for open limit of valve - FBC master card address = 4, Slave ID = 12, Offset = 1.6
- Input module name for close limit of valve– pr: LFA01AA106_C.I

- I/O function for reading close limit of valve – will be selected from PROFIBUS submenu ‘PROFIBUS input’ and ‘BOOL → bin’
- I/O function address for close limit of valve - FBC master card address = 4, Slave ID = 12, Offset = 1.7
- The valve will be closed from pressurized-water tank’s high-level sensor if tank’s level is above 80 %. Therefore, level sensor’s output will be connected to input port ‘foff’ of ‘mgv’ function block.
- The valve will not be opened unless an operator gives permission from the control room by pressing permission switch. Therefore the external continuous input of permission switch connected to external control input port ‘e1’ of ‘mgv’ function block.
- The valve will be monitored from ‘PROFIBUS output', and ‘bin → BOOL’ and the I/O function address - FBC master card address = 4, Slave ID = 12, Offset = 1.4

2. <u>LAA01CT201- Temperature sensor of pressurized-water tank</u>

- Input module name – pr: LAA01CT201.I
- I/O function for reading temperature sensor’s output – will be selected from PROFIBUS submenu ‘PROFIBUS scaled input’ and ‘WORD → ana’.
- I/O function address - FBC master card address = 4, Slave ID = 31, Offset = 21.
- Input signal port ‘av’ of analog measurement function block ‘am’ will be used to read an analog input signal from PROFIBUS module.
- The attributes of PROFIBUS scaled input includes the data required for scaling the measuring range used in Metso DNA CR and the measuring range of the slave device. The attributes of the PROFIBUS scaled input is presented in figure 15 below for LAA01CT201 temperature sensor of pressurized-water tank

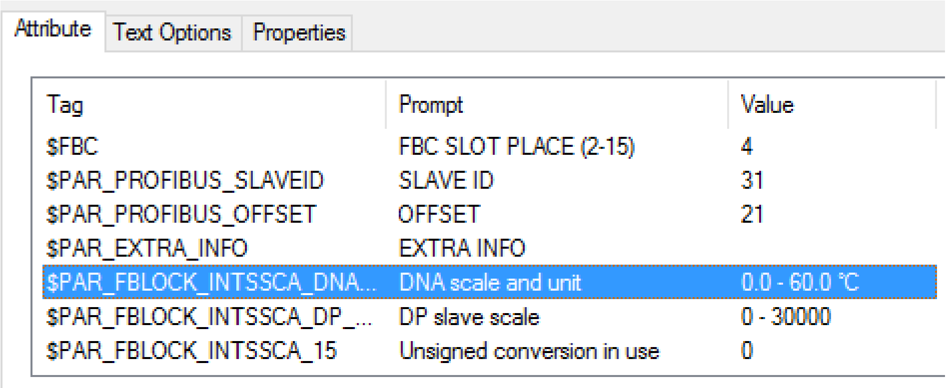

Figure 15. Attributes of PROFIBUS scaled input module

The control room module is a block diagram with the name 'am' for displaying measurement, unit, tag module name etc. in the control room. The attribute of Position function for analog measurement is presented in the following figure, position function will be used for creating tag functions for analog measurement function.

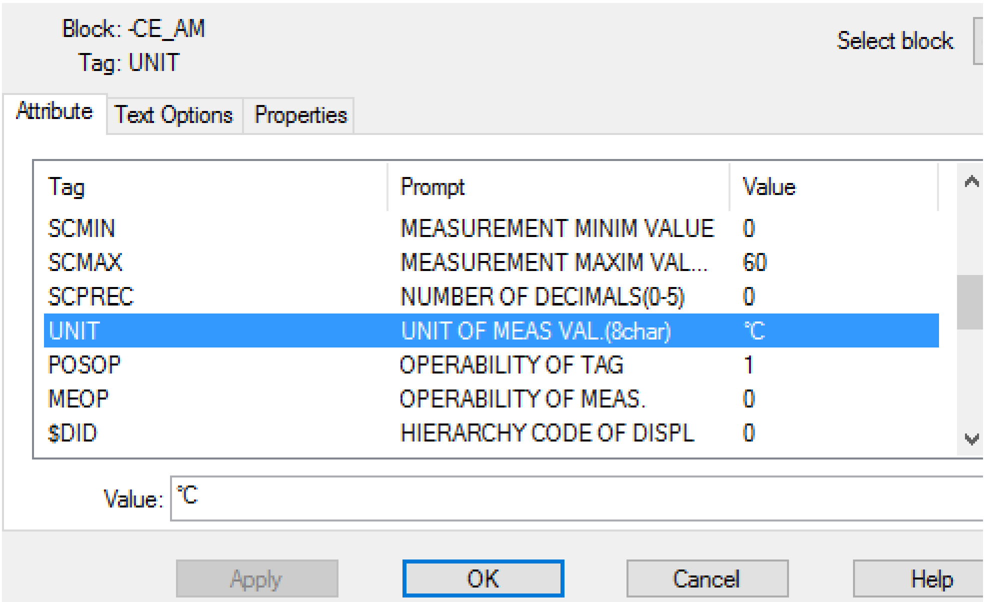

Figure 16. Attributes of Position function for analog measurement

5.3 Design and Schematic Diagram of the Sequence Control Program

Process loops are selected for each module following the flow paths used in the PI diagram before sequence diagrams are drawn. The sequence control program of the energy process is designed according to the following hierarchical structure of a sequence shown in Figure 17 below.

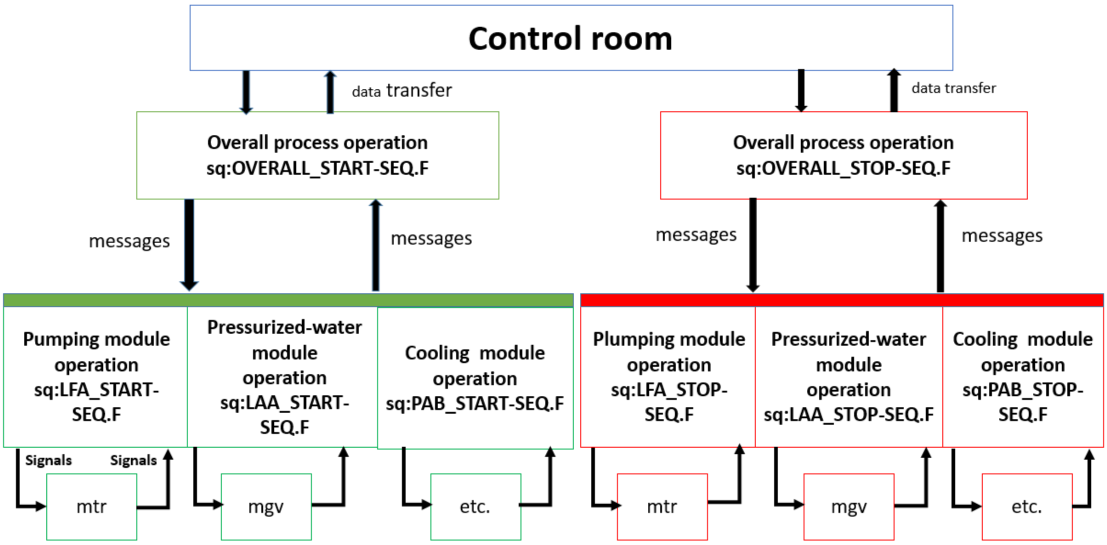

Figure 17. Schematic diagram of energy process sequence control

As can be seen in the figure above, there are two levels of a sequence. On the upper level of the schematic diagram is the sequence management and under the sequence management level there is a linear subsequence. Sequences CADs on the management level are named after the name of the overall process, and the linear Subsequence CADs are named after the name of individual modules they control. The sequence management level consists of a control data structure of type 'seqmng' and the linear subsequence level consists of a control data structure of type 'lseqmng' (Sequence CAD – Manual. 2011, 19-23).

The sequence management data structure 'seqmng' is designed to control the operation of the overall process, in a sequence order beginning first with pumping module, then pressurized-water module, and, at last, cooling module by initiating execution of corresponding linear Subsequence CADs. Thus, starting or stopping of the overall process operation, can be initialized by execution of the Sequence CADs at higher hierarchy level, namely sq:OVERALL_START-SEQ.F or sq:OVERALL _STOP-SEQ.F, which in turn initializes the execution of the corresponding lower hierarchy level Subsequence CADs, which are sq:LFA_START-SEQ.F, sq:LAA_START-SEQ.F, sq:PAB_START-SEQ.F, or sq:LFA_STOP-SEQ.F, sq:LAA_ STOP-SEQ.F, sq:PAB_ STOP-SEQ.F.

The last part of the linear subsequence is a step which consists of the condition, transition, and action function blocks that need to be controlled, whereby the desired signal types are sent to the actuators or field devices to trigger.

The operation of each module can be controlled either from the corresponding subsequence program individually or from the entire sequence program collectively as the overall process.

Sequence loop steps descriptions

This section describes the functions to be controlled in each step, the transition conditions required to take place before proceeding to the next step, waiting time needed for execution of a step, and the alarm time in case of failure or fault.

<u>Parameters</u>

Steps name PCS and OPS=’STARTING’

Steps number (identifier) =1

Single execution of sequence steps (asfmode=0).

Starting overall process operation- OVERALL_START_SEQ.F

The next three steps are parts of entire sequence from OVERALL-START-SEQ.F, which is on sequence management level for initializing and executing of the linear subsequences that relate to individual modules.

Step 1: Starting pumping module's closed loop water circulation from entire sequence control (Appendix 3)

Actions

- The linear subsequence of the pumping module in control of starting operation of the pumping module, whose name is LFA_START_SEQ.F is set to automatic control mode.
- The linear subsequence of the pumping module set to automatic control mode, is given an automatic start command by setting the auto input 'a' on (auto=1).

Transition conditions

- All steps of the linear subsequence of the pumping module that controls starting operation of the pumping module are executed.
- Waiting time is 30 sec, and alarm time is 60 sec.

Step 2: Starting pressurized-water module's closed loop water circulation from entire sequence control (Appendix 4)

Actions

- The linear subsequence of pressurized-water module in control of starting operation of the pressurized-water module, whose name is LAA_START_SEQ.F is set to automatic control mode.
- The linear subsequence of pressurized-water module set to automatic control mode is given an automatic start command by setting the auto input 'a' on (auto=1).

Transition conditions

- All steps of the linear subsequence of pressurized-water module that controls starting operation of the pressurized-water module are executed.
- Waiting time is 20 sec, and alarm time is 60 sec.

Step 3: Starting cooling module's closed loop water circulation from entire sequence control (Appendix 5)

Actions

- The linear subsequence of the cooling module that is in control of starting operation of the cooling module, whose name is LAA_START_SEQ.F is set to automatic control mode.
- The linear subsequence of the cooling module set to automatic control mode is given an automatic start command by setting the auto input 'a' on (auto=1).

Transition conditions

- All steps of the linear subsequence of the cooling module that controls starting operation of the cooling module are executed.
- Waiting time is 30 sec, and alarm time is 60 sec.

Starting pumping module operation- LFA_START_SEQ.F from subsequence

The following five steps are for initializing, starting and keeping up to run the pumping module's closed loop water circulation from a subsequence of the pumping module.

Step 1: An Initial step of the pumping module's subsequence (reference to Appendix 6)

The input interface port into the subsequence the name of which is 'seqadmin', and the output interface port out of the subsequence the name of which is 'subadmin, are inserted at this step.

Actions

- No action needed at this step.

<u>Transition conditions</u>

- No transition condition needed at this step.

Step 2: Tank's level-checkup and safety switches (Appendix 7)

<u>Actions</u>

- No actions needed at this step.

<u>Transition conditions</u>

- High-level switch LFA01CL101 of pumping tank LFA01BB001 is not activated (status=1).
- Level indicator LFA01CL201 of pumping tank LFA01BB001 is not below 15% and above 85%.
- Start-permission's button-state is on (start=0).
- Emergency-stop button is not activated (not activated=0).
- Start-stop's button-state is on (start=1).
- Waiting time is 0 sec, and alarm time is 15 sec.

Step 3: Setting valves and pumps to auto control mode (Appendix 8)

<u>Actions</u>

- Valve LFA01AA101 is set to auto control mode.
- Valve LFA01AA104 is set to auto control mode.
- Valve LFA01AA102 is set to auto control mode.
- Valve LFA01AA106 is set to auto control mode.
- Valve LFA01AA107 is set to auto control mode.
- Control valve LFA01AA202 is set to forced control mode (fc=1).
- Control valve LFA01AA203 is set to forced control mode (fc=1).
- Pump LFA01AP201 is set to auto control mode.
- Pump LFA01AP202 is set to auto control mode.

Transition conditions

- Pump LFA01AP201 is in a standstill position.
- Pump LFA01AP202 is in a standstill position.
- Waiting time is 5 sec, and alarm time 15 sec.

Step 4: Closing and opening valves (Appendix 9)

Actions

- Valve LFA01AA101 is closed.
- Close valve LFA01AA104 is closed.
- Valve LFA01AA102 is opened.
- Forced control input value of valve LFA01AA202 is set to 0%. (‘fcin’= 0 %).
- Valve LFA01AA106 is closed.
- Valve LFA01AA107 is closed.
- Control output value of valve LFA01AA203 is set to 100%. (‘con’= 100 %).
- Start pump LFA01AP202.

Transition conditions

- No transition condition needed at this step.
- Waiting time is 5 sec, and alarm time 60 sec.

Step 5: Starting pump LFA01AP201 (Appendix 10)

Actions

- Pump LFA01AP201 is started.

Transition condition

- No transition needed at this step.

- Waiting time is 5 sec, and alarm time 15 sec.

Step 6: Starting pump LFA01AP202 (Appendix 11)

Actions

- Pump LFA01AP202 is set to run.

Transition condition

- A measured value of water flow with flow meter LFA01CF204 has risen up.
- Waiting time is 5 sec, and alarm time 15 sec.

Step 7: The last step of the subsequence (Appendix 12)

No actions to be executed and no transition needed, hence this is the last step of the subsequence.

5.4 Designing and Application

An operator can start or stop the operation of each individual module directly from a corresponding control room's process picture by pressing the On/Off Subsequence Touch Button as it is shown in figure 13 (page 24) for the pumping module. When LFA-STOP-SEQ Sequence Touch Button is turned on, from the control room, the execution of the sequence program sq: LFA_STOP-SEQ.F takes place, as a result the operation of the pumping module will be started.

Sequence data type 'seqmng' triggers subsequence data type 'lseqmng', when running of the overall process is needed. As seen in figure 19 (page 36) the starting or stopping of the overall process can be initialized by turning on the Overall Start Sequence Touch Button (OVERALL_START.SEQ) or the Overall Stop Sequence Touch Button (OVERALL _STOP.SEQ) from the control room.

5.5 Steam Generator's Data Reading

The steam generator is controlled by Siemens S7 300 PLC located in the field, whereas all other modules are controlled by Metso DNA automation controlling system from the control room. Steam generator's measured process variable values, position of a valve, and statuses of the Touch Buttons are displayed on HMI Control Panel centrally located on the steam generator.

An operator can monitor and control steam generator's field devices from an HMI Control Panel at the field which is physically separated from a control room. As a matter of fact during overall process running there is a need to access all information and data on HMI Control Panel from a control room easily. Function Block CAD and DNAuser interface workstation of Metso DNA engineering tools can be used in order to access the steam generator's data from the control room.

With this intention, first a function block diagram is prepared for each field device, to read the output data from the field devices into I/O functions of the function block diagram. The external input I/O functions need a proper PROFIBUS input Fieldbus address to link with data. Therefore, a unique PROFIBUS DP address was developed for each field device of the steam generator and each HMI Touch Button using the existing Siemens S7 300 PLC input output addresses. (Reference to Appendix 13-15)

For example, the steam generator's pressure transmitter HAD01CP201 has I/O address of 4.0 as Siemens S7 300 slave device. The corresponding PROFIBUS DP I/O address for the pressure transmitter is 5.51.7 as derived based on Siemens S7 300 address data type. (Reference to Appendix 14) The function block diagram is prepared as seen in figure 18 for pressure transmitter using the PROFIBUS DP I/O address to read the output data of pressure transmitter using the PROFIBUS DP master. PROFIBUS DP master can access into Siemens S7 300 data as a DP slave when only memory card of Siemens S7 300 is replaced by a slave card. Once the interface between the DP master and the slave card is established, the DP master sends the address of the field device to the slave device, Siemens S7 300 in a request to access the content of the slave device. Consequently, the slave device Siemens S7 300 responds to the request.

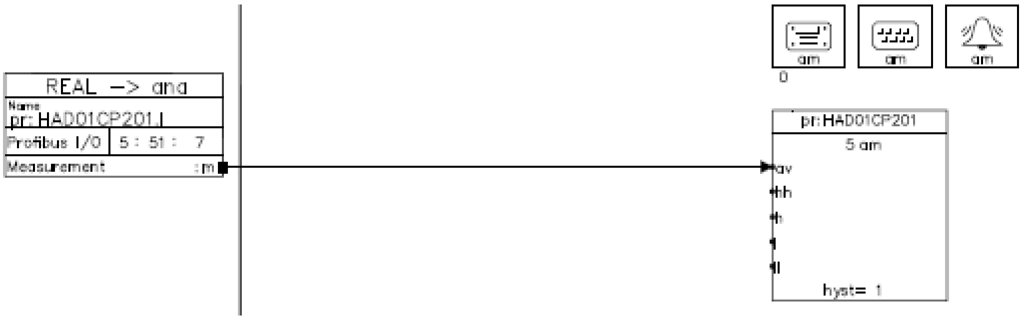

Figure 18. Function block diagram for pressure transmitter HAD01CP201 of Steam generator

Secondly, a process picture is prepared for those field devices to read the corresponding data of each slave device into a control room, which is only one way communication. The DP master reads only data of the field devices, however it has no access to write data or monitor the field devices. The process picture of the steam generator and the instantaneous measured value is shown in the figure below.

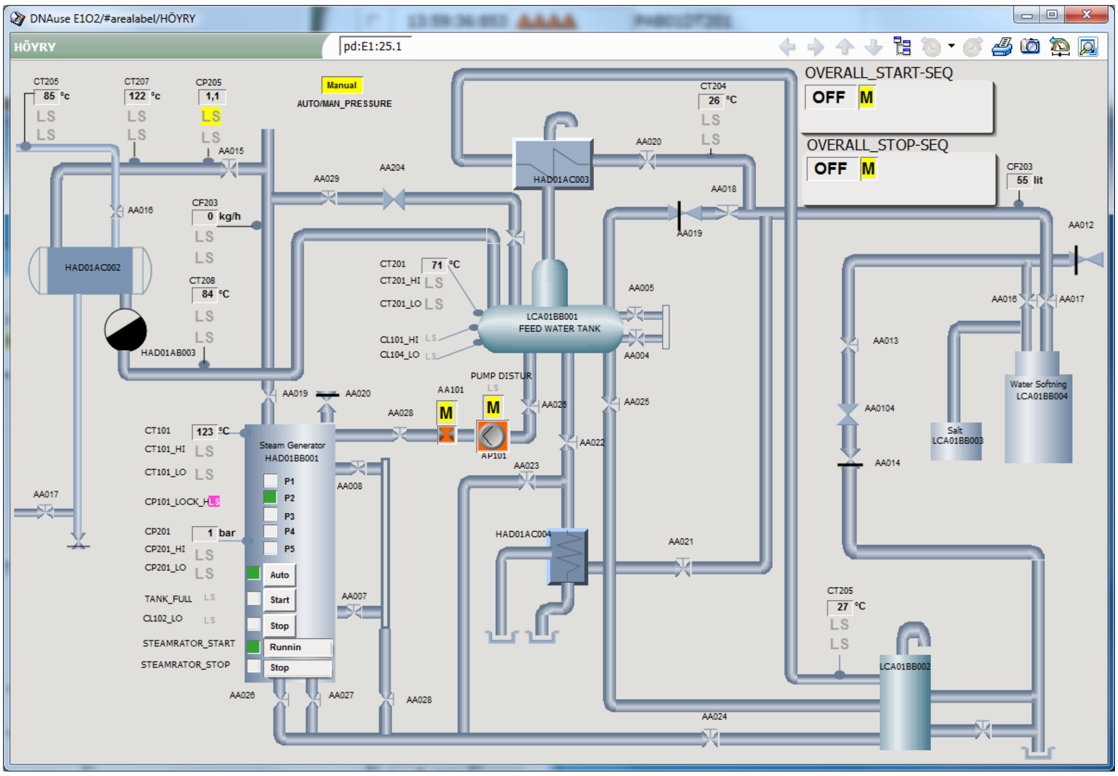

Figure 19. Instantaneously measured value of Steam generator

6 Testing and Outcome of Testing

6.1 Testing FbCAD and SeqCAD

Many tests are carried out to check the proper operation of the FB CAD, sequence CAD, and process picture in accordance with the functional description of the energy process system.

Function Test, a graphical testing tool is used for testing the functionality of the function diagrams. The function test can be used with both Function Block CAD and Sequence CAD. The I/O functions of the function block diagram are tested by opening a Test command from the File menu and clicking the Run button from the list opened as can be seen in figure 20 below. During the test, binary connection's input output values are '1' or '0'. '1' indicates that the status of the port is active or on, and '0' indicates that the status of the port is off or not active.

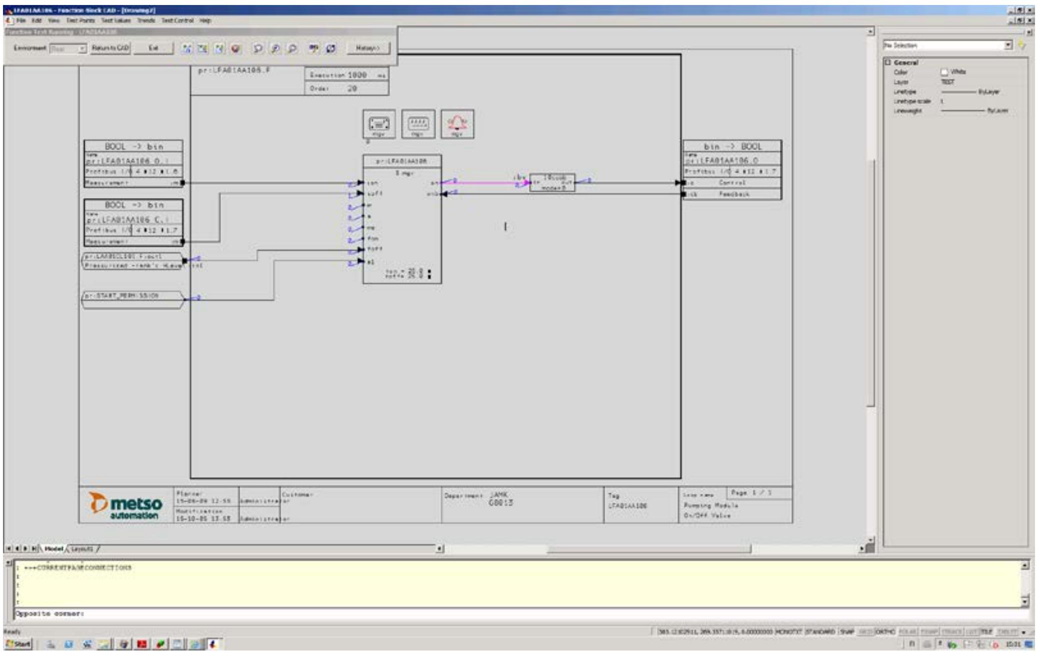

Figure 20. Function Block CAD test from DNA explorer

Function test of Sequence CAD is started by opening the desired sequence step diagram and then by selecting a Test command from the File menu and clicking Run button same way as FbCAD. Then by pressing on the On/Off Sequence Touch Button from the process picture's Sequence loop window testing will be activated. Test signals change one after the other within fractions of a second as the function diagrams of Sequence CAD are executed, which is a slightly difficult to follow the signal's change with eyes.

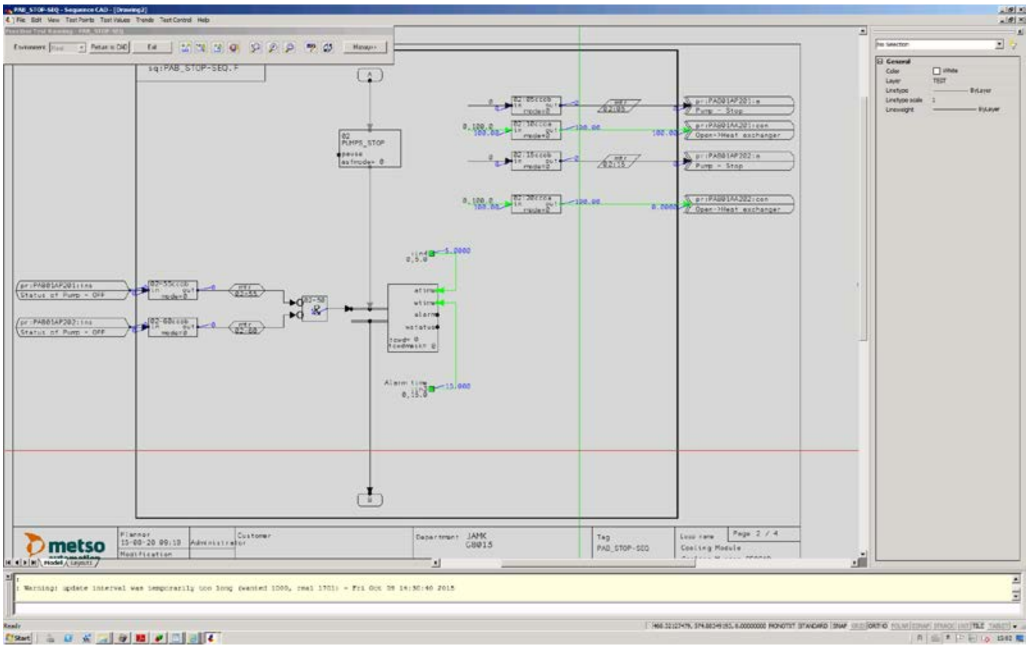

Figure 21. Function test of Sequence CAD

The field devices of energy process can be controlled manually or automatically. An operator can switch between auto and manual control mode from the control room.

Due to a safety switch or interlocking the controlled device can be switched to forced off or stopped to protect the device and the energy process system, as a result of this it is not possible either manually or automatically to drive the device. In such a situation, more information about the status of the field device can be found in the loop windows display, as shown in figure 22 below.

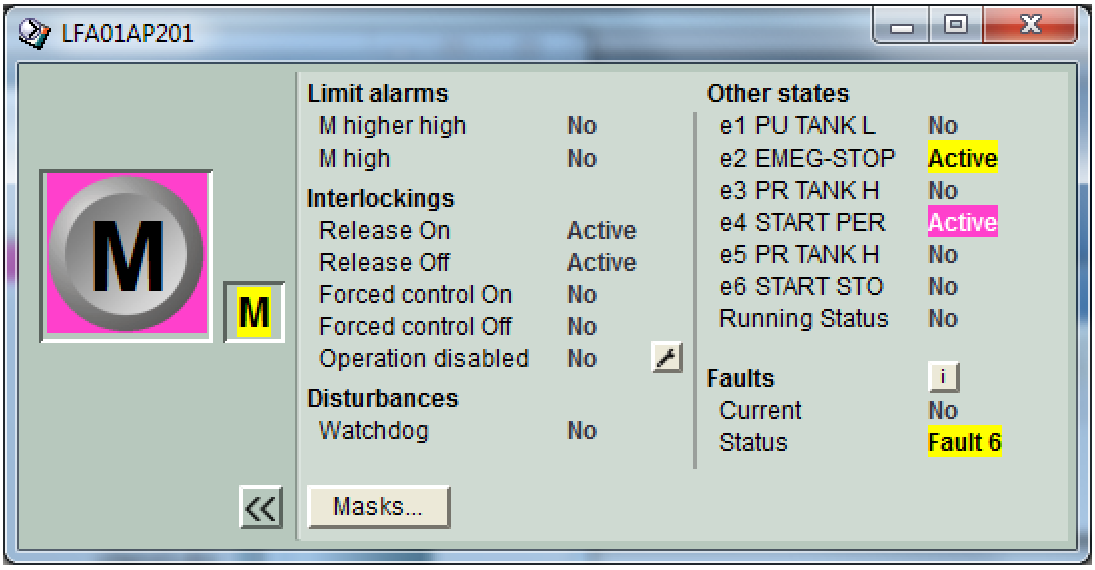

Figure 22. Control loop window display of pumping module's pump

6.2 Testing functions of the process loops

As it has been mentioned already, there are three Subsequence CADs prepared, one for each of the three modules required to run sequentially. The Sequence CAD was prepared for each module following the process loop, which was selected according to the function required to carry out.

The function of the selected process loop of the pumping module is to supply water to pressurized-water module when water is required. This task is carried out by two pumps running in series, namely LFA01AP202 and LFA01AP201 with the aid of PID Controller LFA01DL201. When the level of the pressurized- water tank drops below the lower limit set by an operator, PID Controller LFA01DL201 gives a command, which sets the two pumps to pump water into the pressurized-water tank. The test has been carried to check the performance of the process loop's Sequence CAD. The process loop can supply water into the pressurized-water tank, whereas it cannot regulate pressurized-water tank's level. As a result, the application of the PID Controller LFA01DL201 was eliminated for the time from the Subsequence CAD of the pumping module's process loop.

The function of the pressurized-water module's process loop is to inject water into the steam generator when water is required, which occurs rarely. The task of injecting water is carried out by keeping pump LAA01AP201 to run continuously as it can be seen in figure 1 (page 8). When the Sequence CAD of the pressurized-water module’s process loop is executed, it operates properly to carry on a function, thus ensuring that the injection of water could take place, when water is required.

The task of cooling module’s process loops is to cool steam from the steam generator by transferring heat to cooling loops as can be seen in figure 2 (page 9). According to requested set point of temperature, the rate of heat transfer could be regulated by running the two pumps of the module (PAB01AP202 and PAB01AP201) with the aid of PID Controllers, namely, PAB01DT201, PAB01DT202, and PAB01DT203. Test carried out on the Sequence CAD of the cooling module’s two process loops (loop A and B), shows that the Sequence CAD function properly as intended to be.

Finally, many efforts and tests were carried out with the intention of setting transition conditions between each successive module of the Overall Start Sequence CAD. The objective of the transition conditions was to avoid starting the operation of the module if its previous adjacent module is not in running state. In such a way, starting the operation of the pressurized-water module could be avoided, if the pumping module is not in a running state. In the same way also starting the operation of the cooling module could be avoided, if the pressurized-water module is not in a running state. The intention of using the transition conditions was canceled for the time being after all efforts and tests had turned out to be ineffective. As a result, the Overall Start Sequence CAD was prepared as in Appendix 3, 4 and 5.

6.3 Outcome of testing

One of the main objectives of the thesis was to control operations of pumping module, pressurized-water module, and a cooling module, in such a way that they could be started collectively in a sequence from one point of a Sequence Touch Button and stopped from another point of a Sequence Touch Button. By turning on or off the overall Sequence Touch Button of a process picture from the control room, henceforth it is possible to control all three modules of the energy process sequentially. Of course, there are some unaccomplished tasks as mentioned already under the title of testing the functions of the process loops, which could restrict the application of some essential functions, but not the sequence control totally.

Accessing on the HMI Control Panel displayed data of steam generator from the control room gives an operator very realistic and instantaneous view of the steam generator’s functions. The task of accessing steam generator’s data displayed on the HMI Control Panel from the control room was carried out successfully. As a result, an operator can easily follow the measured process variable values and statuses of Touch Buttons directly from a control room. The operator does not need to be in the same room where the steam generator is anymore unless controlling or monitoring of the steam generator’s functions is required.

6.4 Conclusion

The energy process of the energy technology laboratory is a model of a district heating plant. It has the specific features of district heating system such as supplying water, pressurizing water, injecting pressurized water into a steam evaporator, and cooling water system. Furthermore, it is equipped with the most important operational and functional requirements such as monitoring the system, regulating variables, process orders and so on.

Nowadays, systems of a process plant operate in a combination of a prescribed order for a period of time by themselves automatically with little human effort or without human intervention once they are started. In such a case, sequence control program is applied to control all successive steps of the overall process to achieve the end result needed.

In order to optimize energy process system of energy technology laboratory to the real plant process standard, it is necessary to develop the relevant controlling system, so that students can learn the real plant-based techniques. As a result, automation students can benefit from the task of this thesis as has been noted already by being acquainted with the sequence control program developed.

This thesis can be further developed in many ways by applying more advanced control techniques. PID controller LFA01DL201, which regulates pressurized-water tank's level with the aid of pump LFA01AP202 is one of the areas, where further development is needed. Implementing PID controller LFA01DL201 enables the overall process to run for longer time continuously by ensuring extra water supply, and minimizing a need for an operator intervention.

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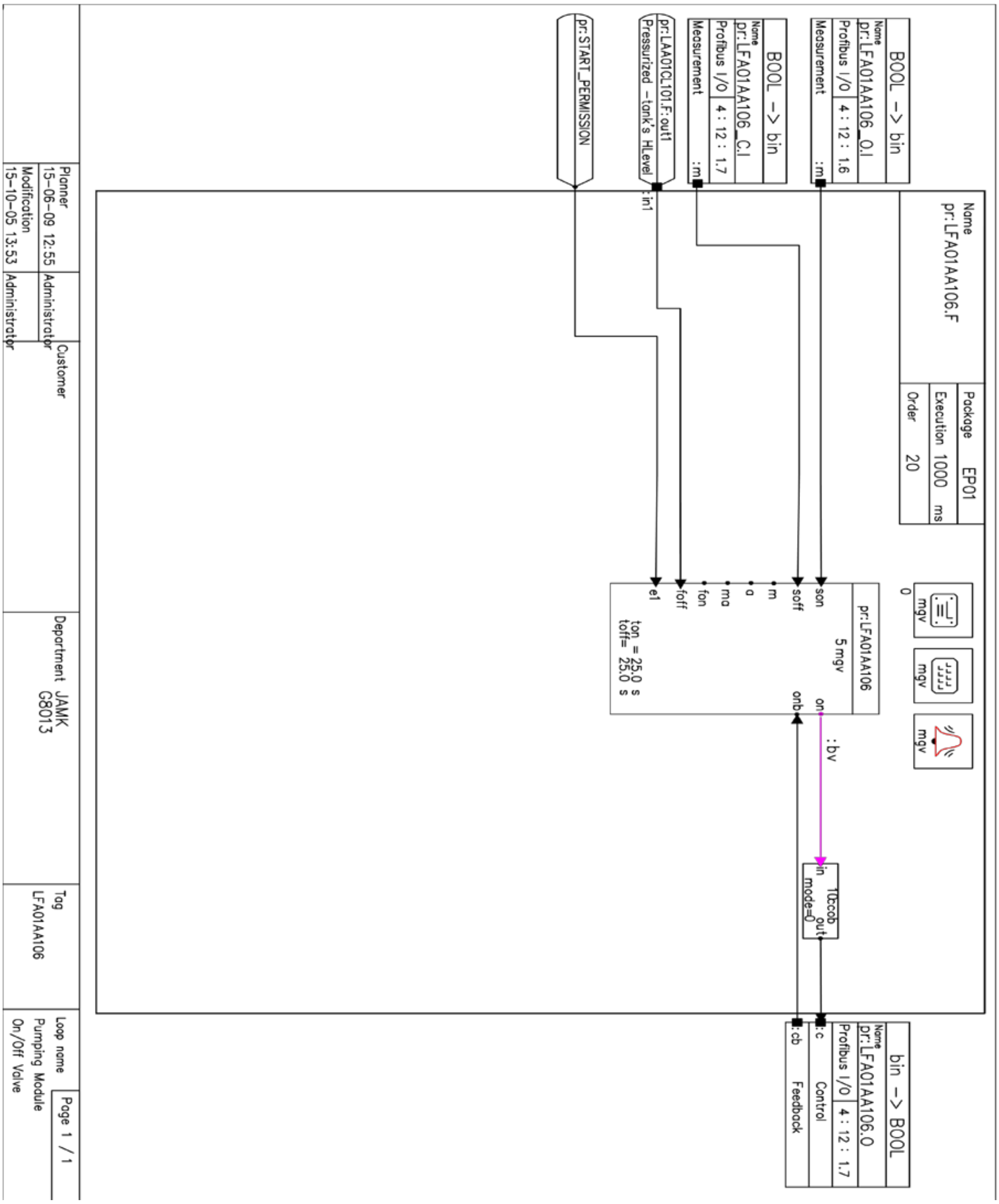
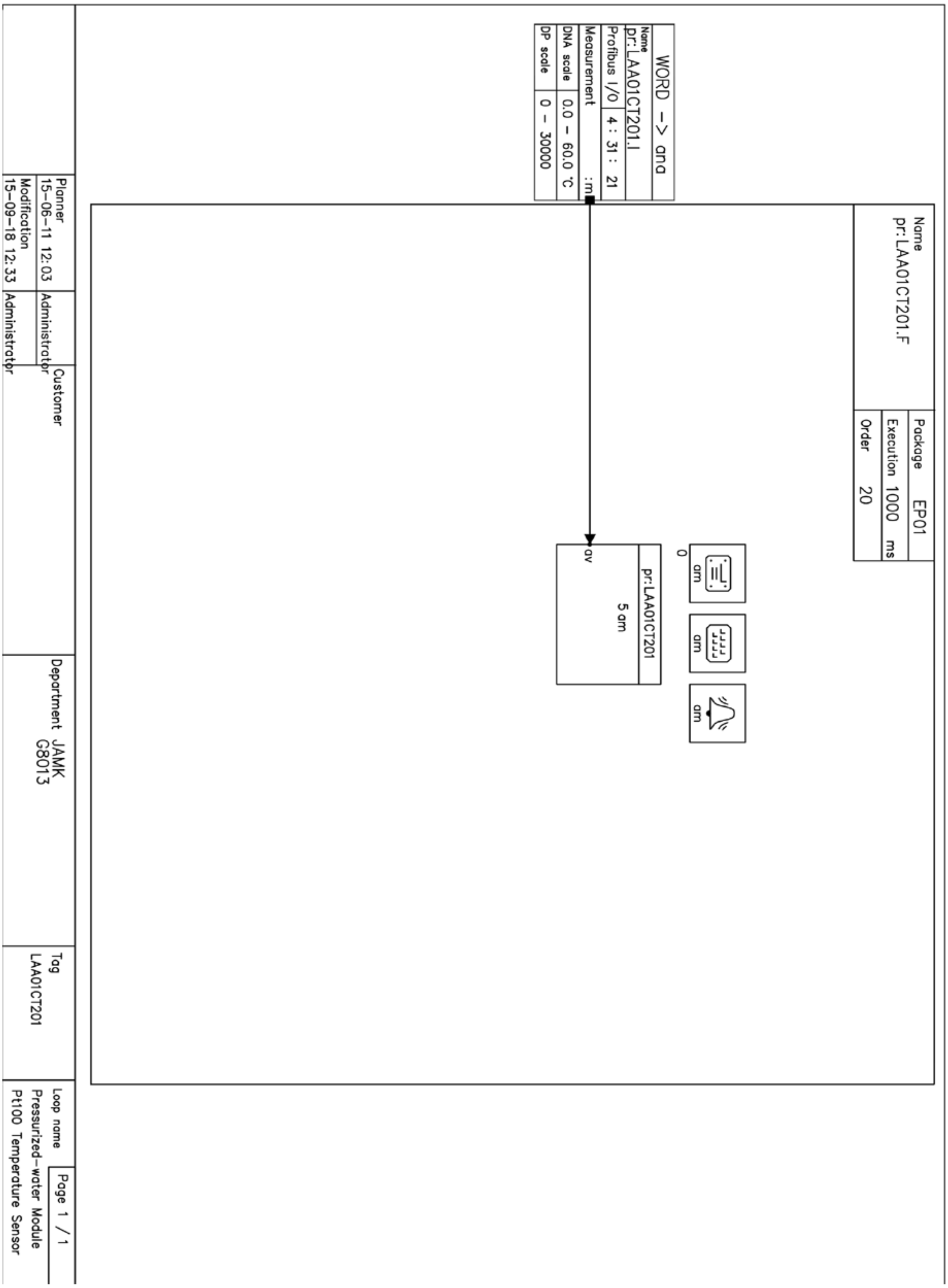
Appendices

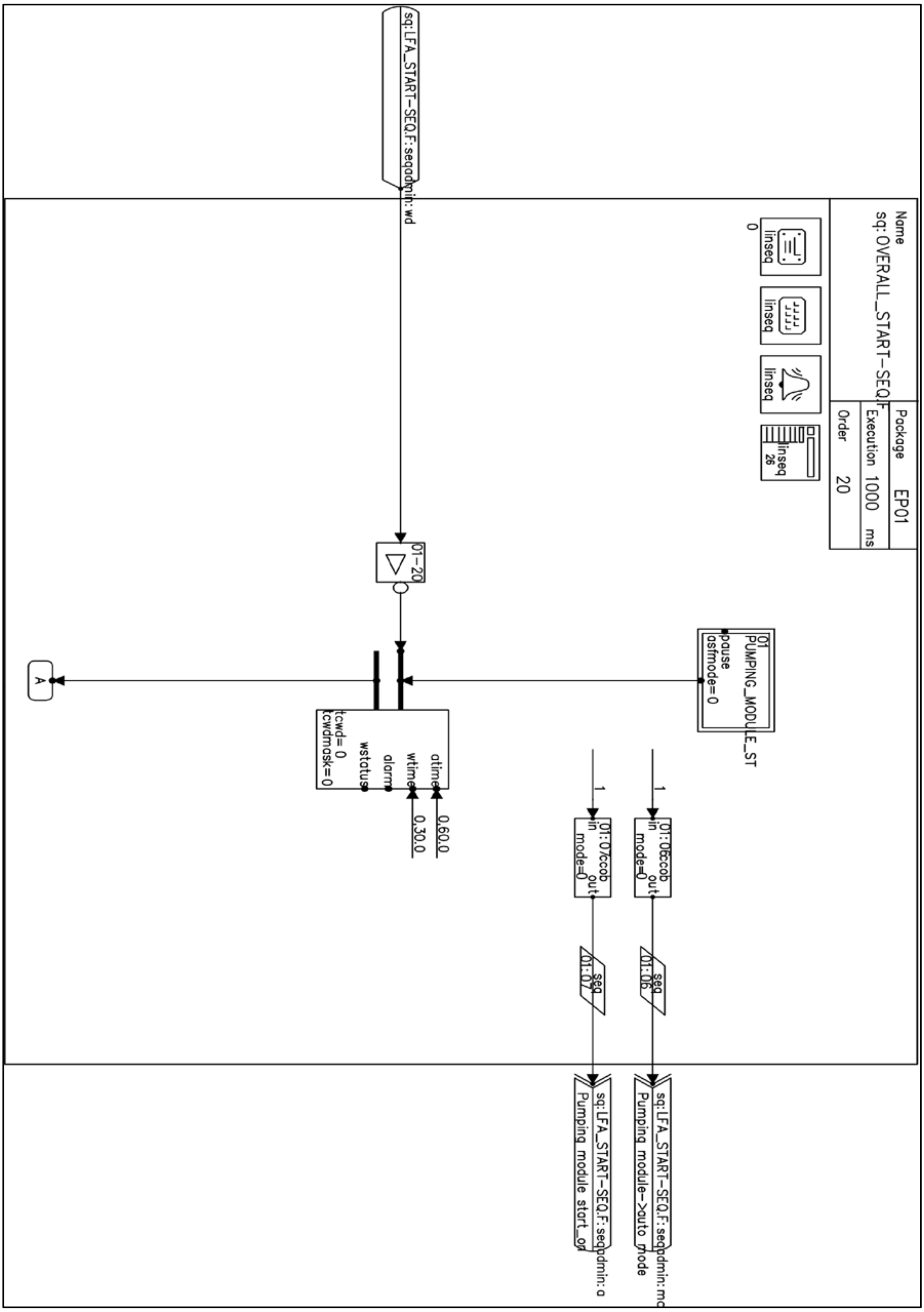
Appendix 1. LFA01AA106-On/Off valve from pumping module



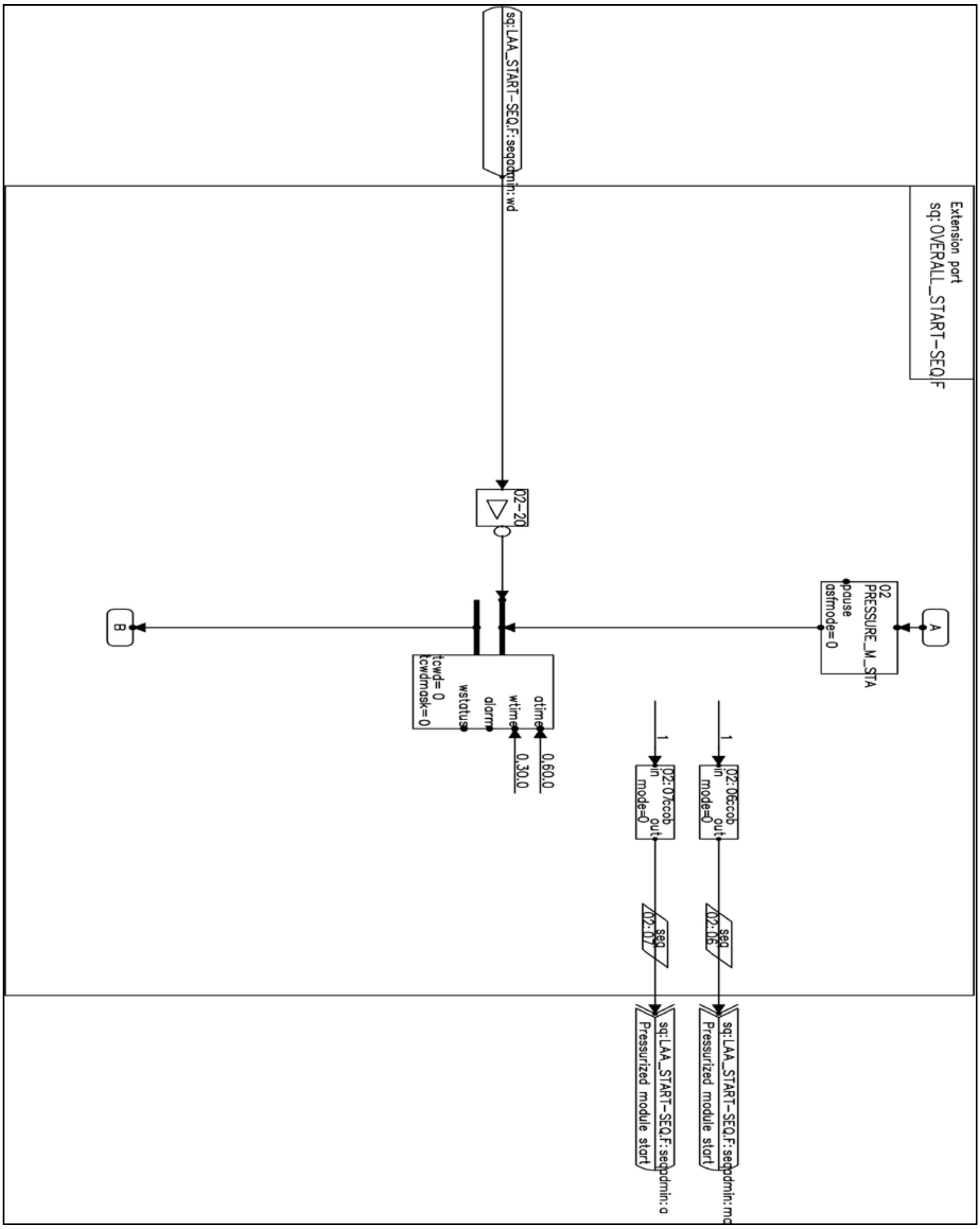
Appendix 2. LAA01CT201- Temperature sensor of pressurized-water tank



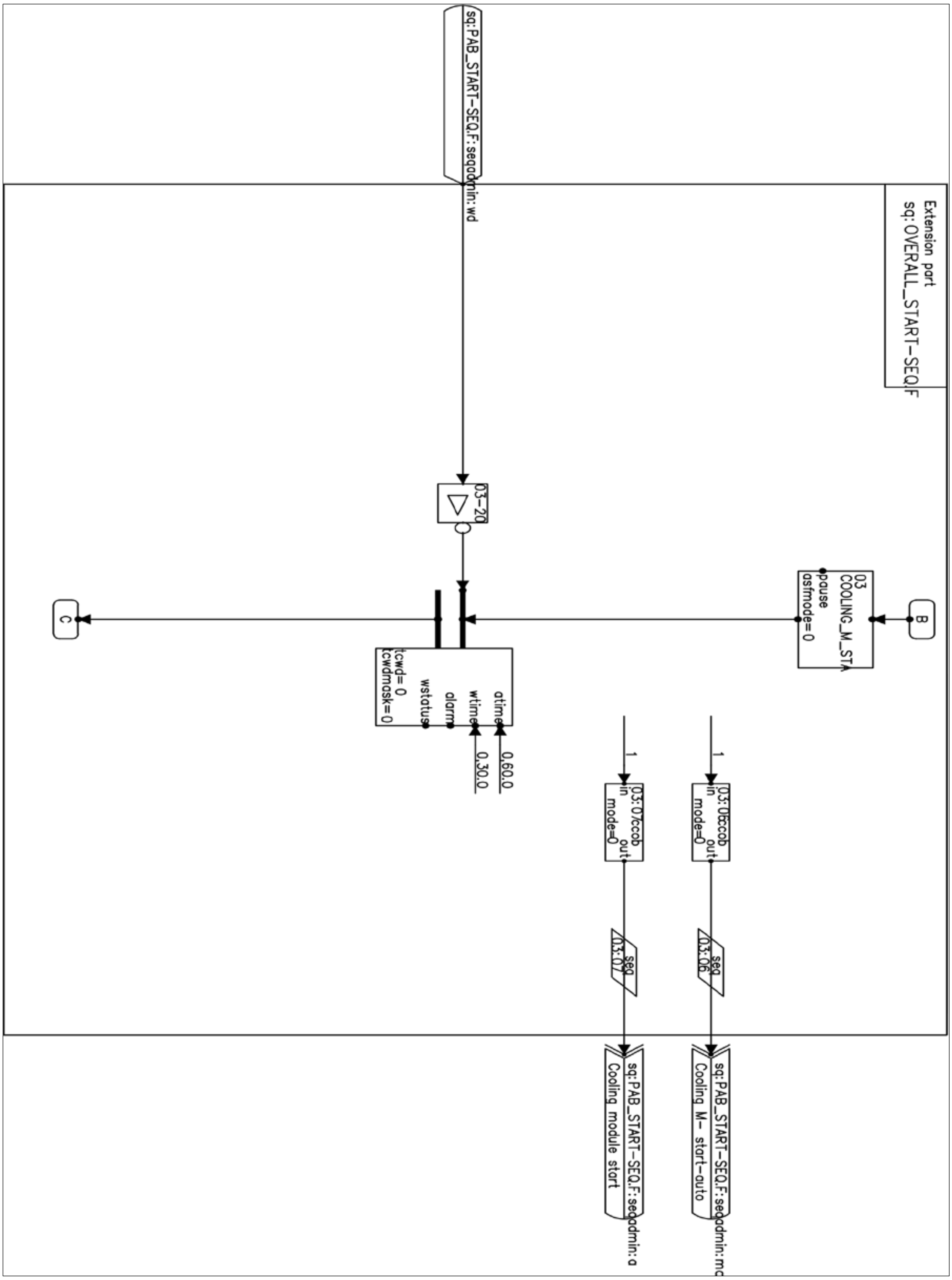
Appendix 3. Step 1: OVERALL_START_SEQ.F



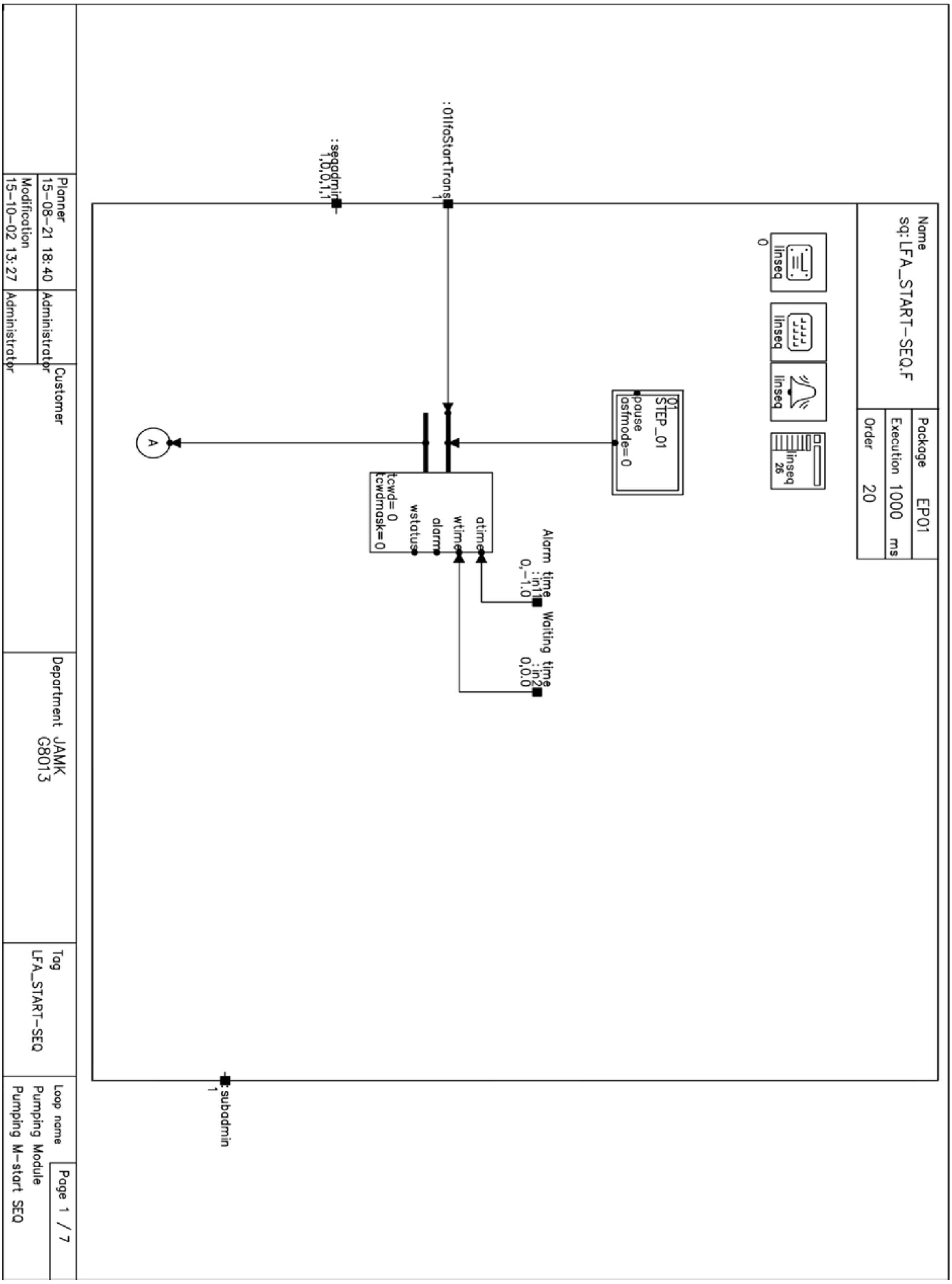
Appendix 4. Step 2: Starting pressurized-water module from entire sequence control



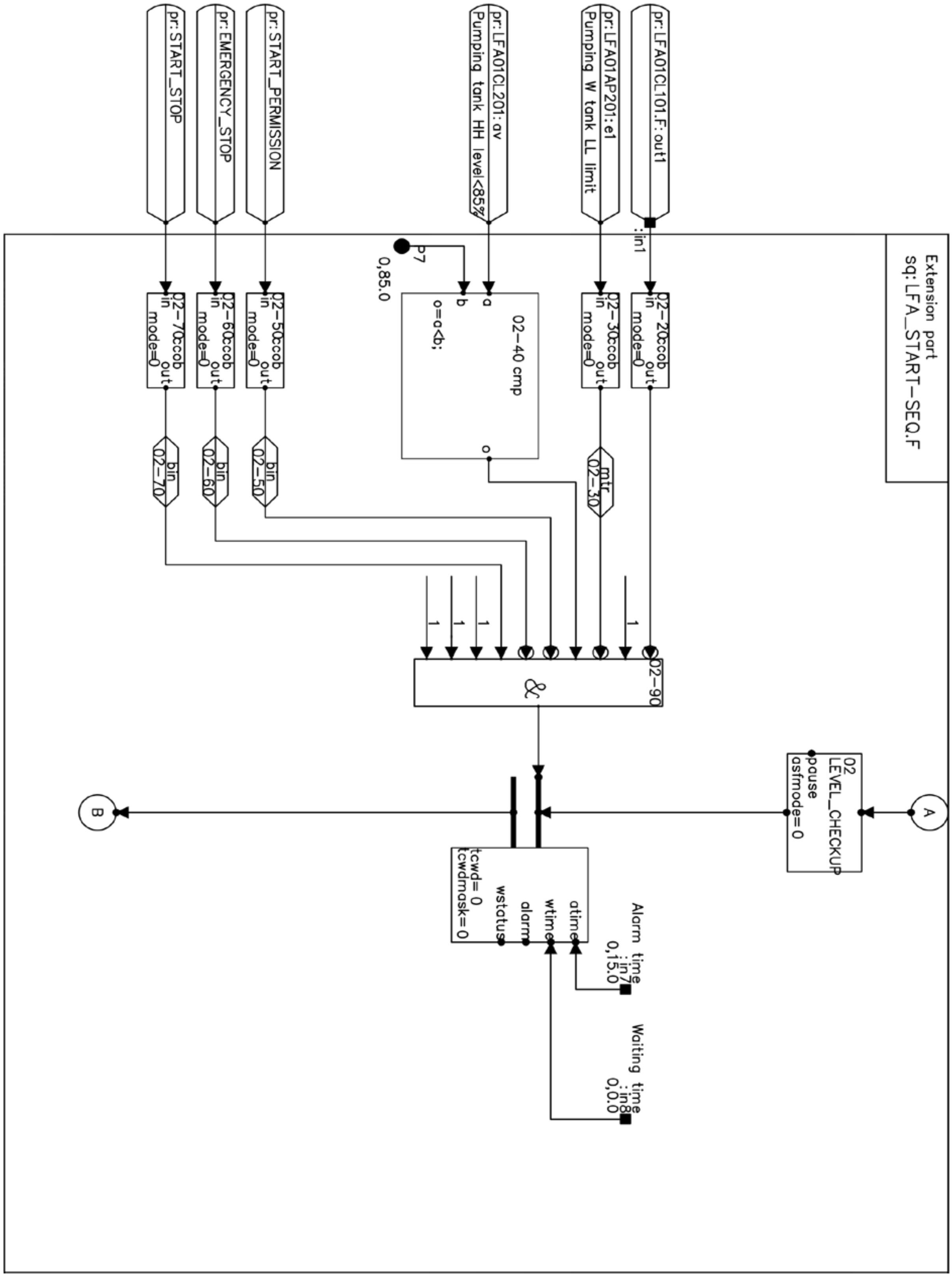
Appendix 5. Step 3: Starting cooling module from entire sequence control



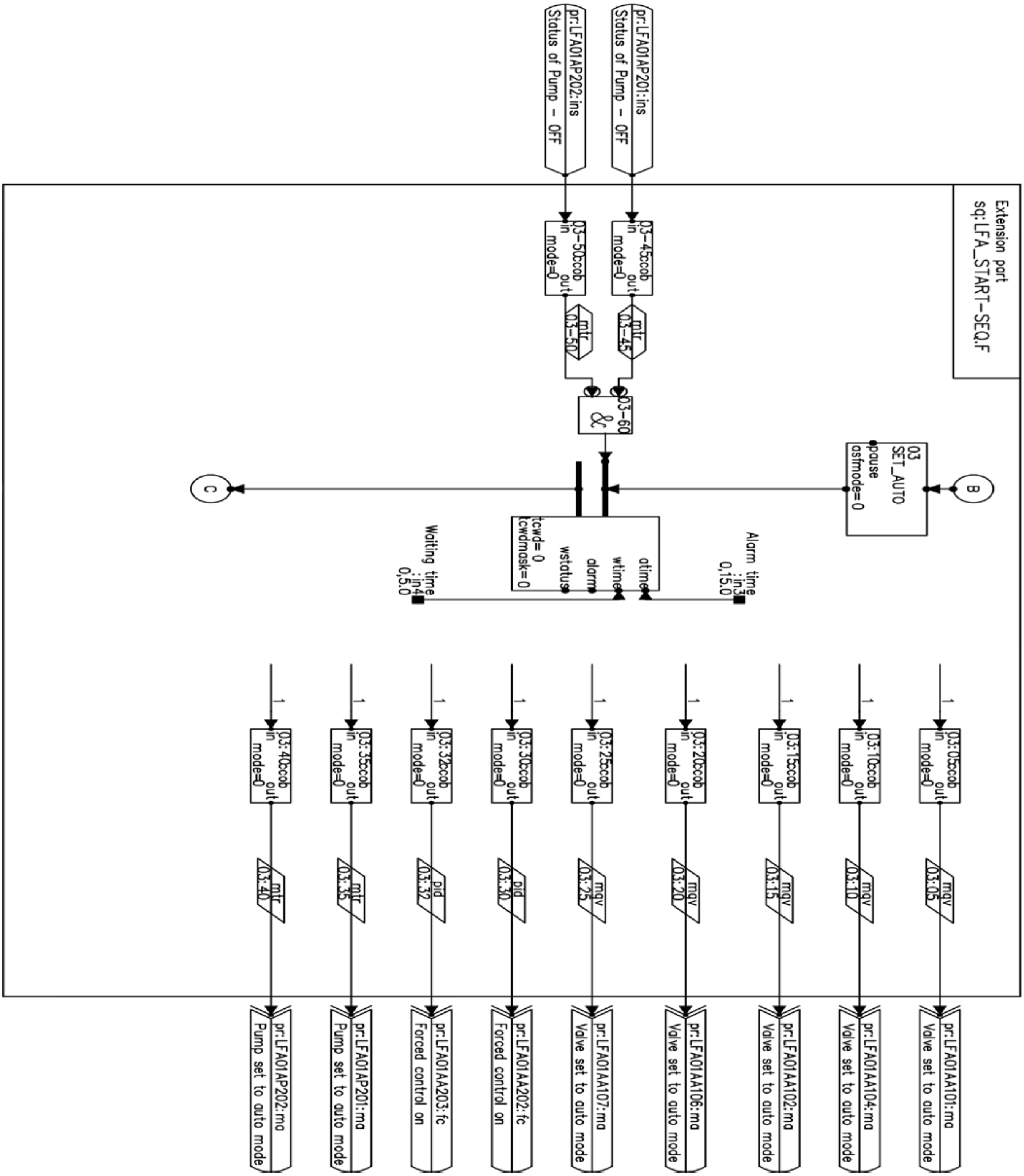
Appendix 6. Step 1: An initial step of pumping module



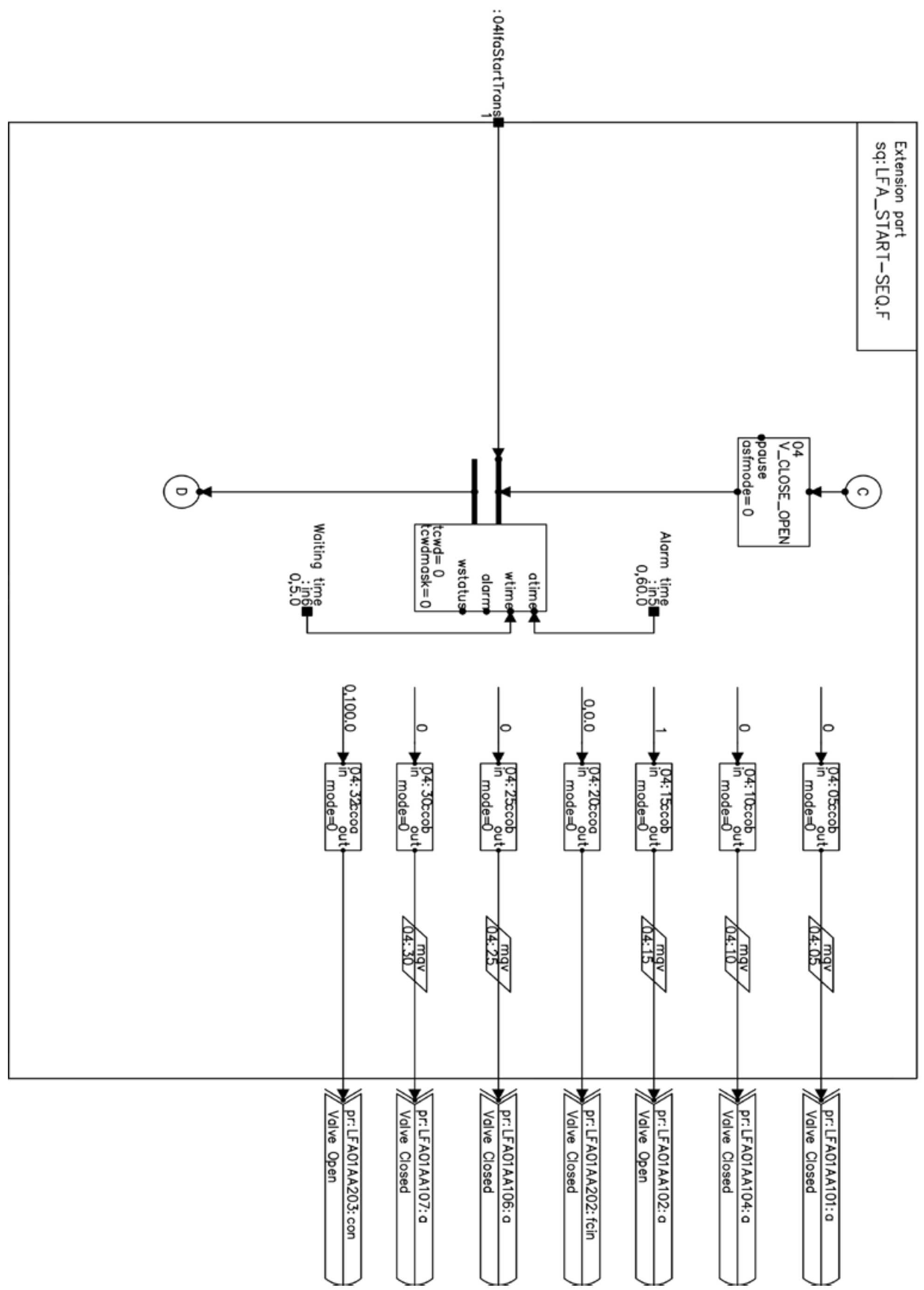
Appendix 7. Step 2: Tank's level-checkup and safety switches



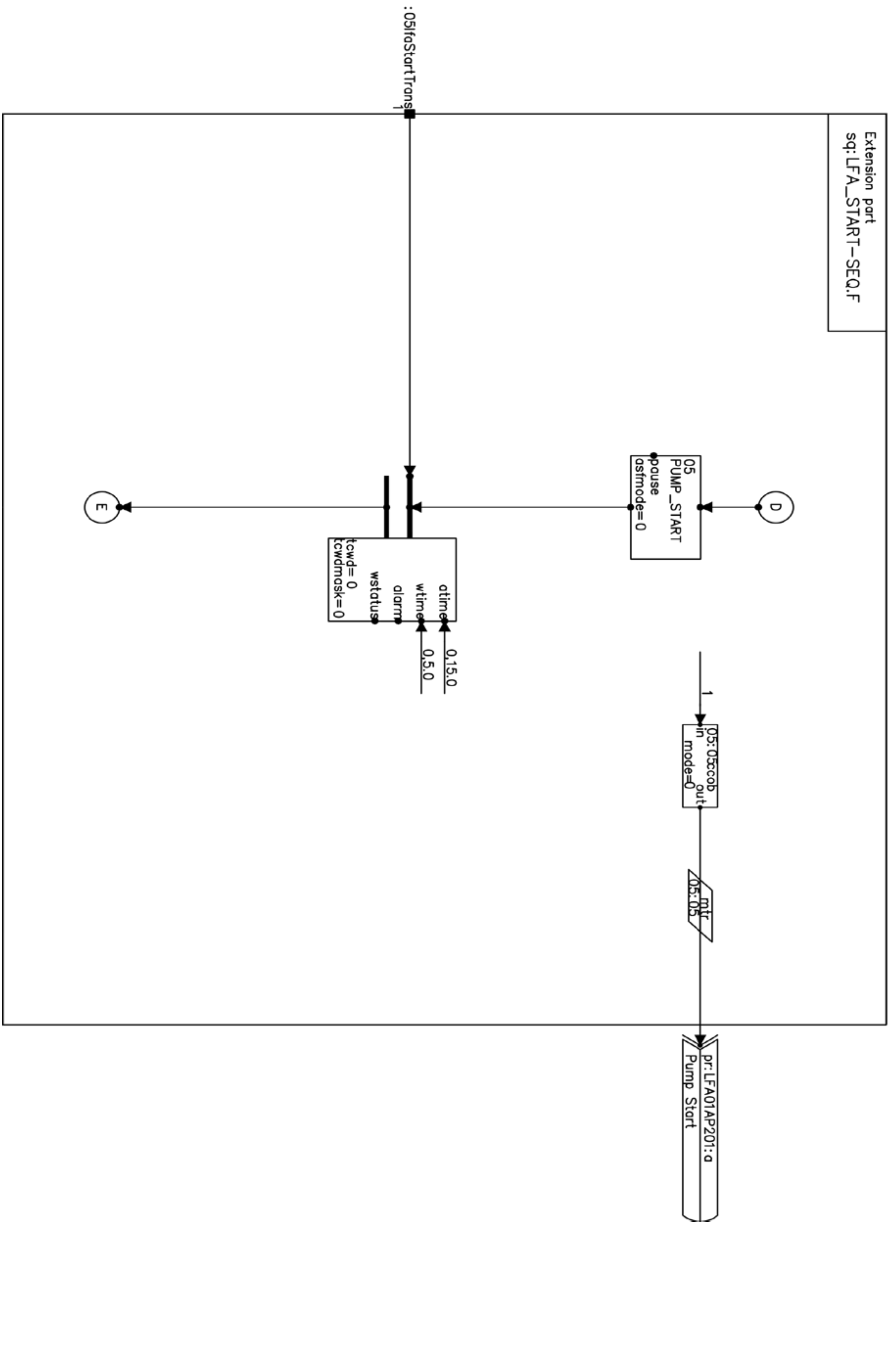
Appendix 8. Step 3: Setting valves and pumps to auto control mode



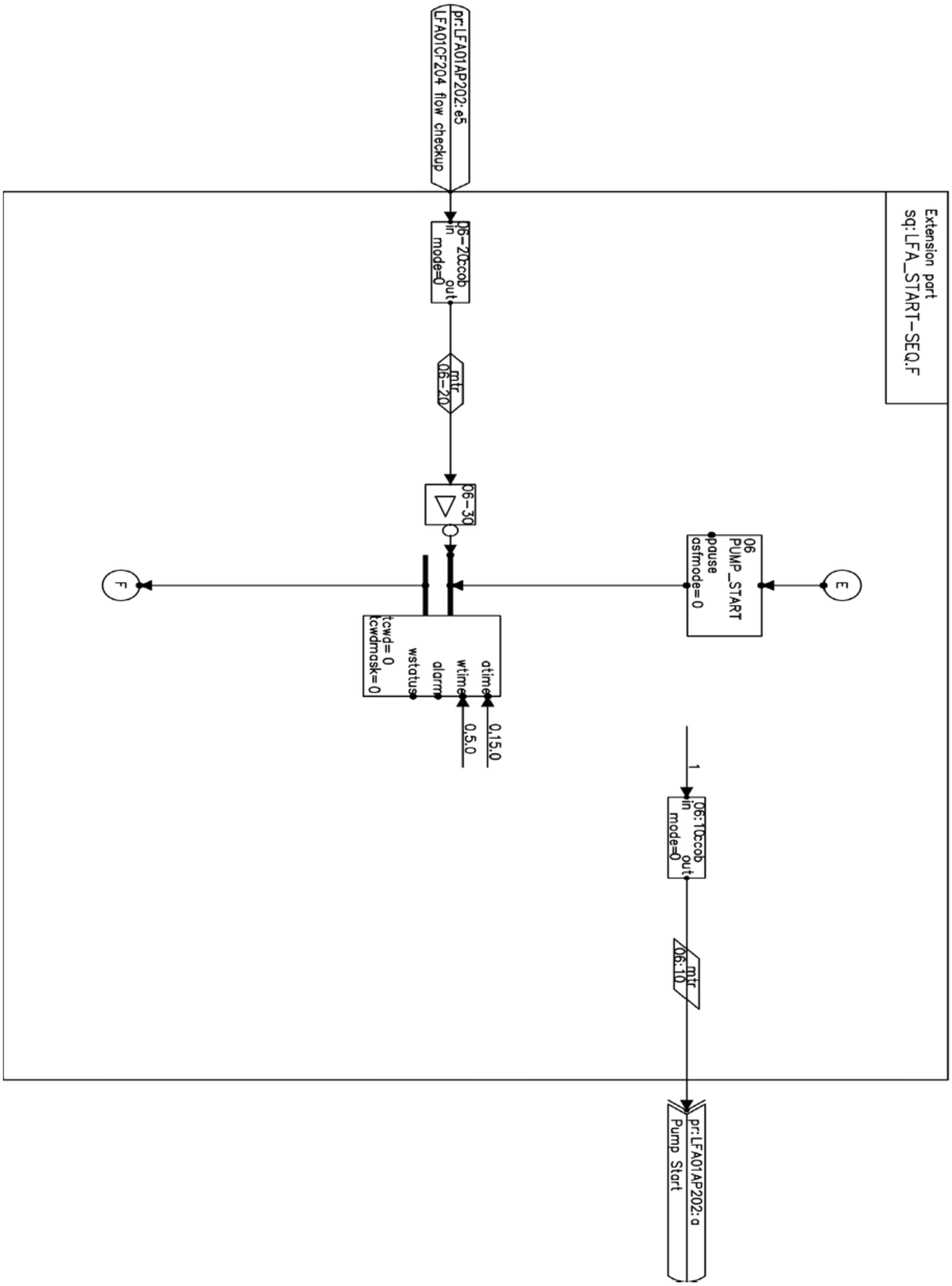
Appendix 9. Step 4: Closing and opening valves



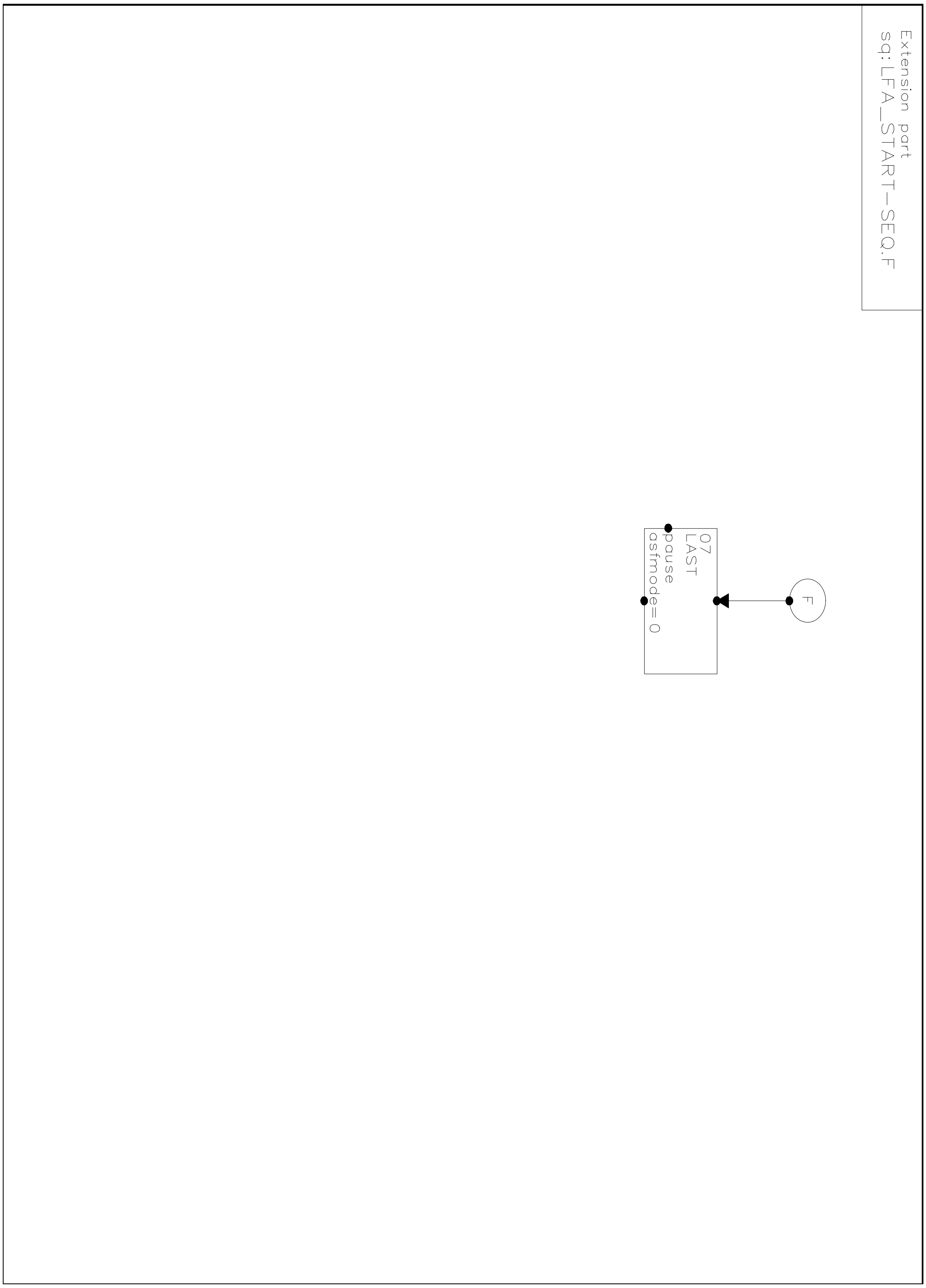
Appendix 10. Step 5: Starting pump LFA01AP201



Appendix 11. Step 6: Starting pump LFA01AP202



Appendix 12. Step 7: The last step of the pumping module



Appendix 13

Table 1. PROFIBUS IO address of Siemens S7 300 slave devices

DB1--"Comm_DB" --Energiatek_prosessi_new\Pannu\CPU313-2 DP\---\DB1						
Siemens S7 300 IO Address	FBCAD PROFIBUS IO ADDRESS	Name	MetsoDNA TAG_CODE	Type Struct	Initial value	Comments
0.0	5.51.0,0	start	HAD01BB001_START	BOOL	FALSE	Kehittiemen käynnistys
0.1	5.51.0,1	stop	HAD01BB001_STOP	BOOL	FALSE	Kehittimen pysäytys
0.2	5.51.0,2	teho1	POWER_1	BOOL	FALSE	Teho 1 valinta
0.3	5.51.0,3	teho2	POWER_2	BOOL	FALSE	Teho 2 valinta
0.4	5.51.0,4	teho3	POWER_3	BOOL	FALSE	Teho 3 valinta
0.5	5.51.0,5	teho4	POWER_4	BOOL	FALSE	Teho 4 valinta
0.6	5.51.0,6	teho5	POWER_5	BOOL	FALSE	Teho 5 valinta
0.7	5.51.0,7	hoyryP_AM	STEAM_P_AM	BOOL	FALSE	Höyryn painesäätö auto/man
1.0	5.51.1,0	syveLT_AM	FEEDTANK_T_AM	BOOL	FALSE	Syöttövesisäiliön lämpötilasäätö auto/man
1.1	5.51.1,1	taytto	HAD01CL101	BOOL	FALSE	Kehittimen täyttö
1.2	5.51.1,2	teho_AM	POWER_AM	BOOL	FALSE	Tehon valinta auto/man
1.3	5.51.1,3	laskuri_nol	COUNTER_RESET	BOOL	FALSE	Vesilaskurin nollaus
1.4	5.51.1,4	vara4		BOOL	FALSE	
1.5	5.51.1,5	vara5		BOOL	FALSE	
1.6	5.51.1,6	vara6		BOOL	FALSE	
1.7	5.51.1,7	vara7		BOOL	FALSE	
2.0	5.51.2,0	pumpu_kay	LCA01AP101	BOOL	FALSE	Syttövesipumppu käy
2.1	5.51.2,1	elmo_mg_auki	LCA01AA101	BOOL	FALSE	Elmon magneettiventtiili auki
2.2	5.51.2,2	elmo_on	HAD01BB001_PER	BOOL	FALSE	Kehitin käynnissä
2.3	5.51.2,3	elmo_valmis	HAD01BB001_READY	BOOL	FALSE	Kehitin käynnistysvalmis
4.0				END_STRUCT		

Appendix14

Table 2. PROFIBUS IO address of Siemens S7 300 slave devices

DB10--"Mittaus_DB" --Energiatek_prosessi_new\Pannu\CPU313-2DP\---\DB1						
Siemens S7 300 IO Address	FBCAD PROFIBUS IO ADDRESS	Name	MetsoDNA TAG_CODE	Type Struct	Initial value	Comments
0.0	5.51.3	Elmo_LT	HAD01CT101	REAL	0.000000e+000	Höyryn lämpötila kehttimessä
4.0	5.51.7	Elmo_P	HAD01CP201	REAL	0.000000e+000	Höyryn paine kehittimessä
8.0	5.51.11	Elmo_F	HAD01CF203	REAL	0.000000e+000	Lähtevän höyryn virtaus
12.0	5.51.15	Hoyry_P	HAD01CP205	REAL	0.000000e+000	Lähtevän höyryn paine
16.0	5.51.19	Hoyry_LT	HAD01CT207	REAL	0.000000e+000	Lähtevän höyryn lämpötila
20.0	5.51.23	LV_LT	HAD01CT205	REAL	0.000000e+000	Veden lämpötila lämmönvaihtimen jälkeen
24.0	5.51.27	Hoyry_LV_LT	HAD01CT208	REAL	0.000000e+000	Höyryn lämpötila lämmönvaihtimen jälkeen
28.0	5.51.31	Syve_LT	LCA01CT201	REAL	0.000000e+000	Syöttövesisäilliön lämpötila
32.0	5.51.35	Kylma_LT	LCA01CT204	REAL	0.000000e+000	Kylmän veden lämpödtila ennen hönkalaudtinta
36.0	5.51.39	Honka_LT	LCA01CT205	REAL	0.000000e+000	Veden lämpötila hönkälauhduttimen jälkeen
40.0	5.51.43	vesimaara	LCA01CF203	REAL	0.000000e+000	Pehmennetyn veden määrä
44.0		vara2		REAL	0.000000e+000	
48.0		vara3		REAL	0.000000e+000	
52.0		vara4		REAL	0.000000e+000	
56.0		vara5		REAL	0.000000e+000	
60.0		vara6		REAL	0.000000e+000	
64.0		vara7		REAL	0.000000e+000	
68.0		vara8		REAL	0.000000e+000	
72.0		vara9		REAL	0.000000e+000	
76.0		vara10		REAL	0.000000e+000	
80.0				END_STRUCT		

Appendix 15

Table 3. PROFIBUS IO address of Siemens S7 300 slave devices

Siemens S7 300 IO Address	FBCAD PROFIBUS IO ADDRESS	Name	MetsoDNA TAG_CODE	Type Struct	Initial value	Comments
0.0	5.51.47.0	Elmo_LT_Hi	HAD01CT101_HI	BOOL	FALSE	Höyrykehittimen lämöptila ylärajahälytys
0.1	5.51.47.1	Elmo_LT_LO	HAD01CT101_LO	BOOL	FALSE	Höyrykehittimen lämöptila alarajahälytys
0.2	5.51.47.2	Elmo_P_Hi	HAD01CP201_HI	BOOL	FALSE	Höyrynkehittimen paine alarajahälytys
0.3	5.51.47.3	Elmo_P_Lo	HAD01CP201_LO	BOOL	FALSE	Höyrynkehittimen paine ylärajahälytys
0.4	5.51.47.4	Elmo_F_Hi	HAD01CF203_HI	BOOL	FALSE	Lähtevän höyryn virtaus ylarajahälytys
0.5	5.51.47.5	Elmo_F_Lo	HAD01CF203_LO	BOOL	FALSE	Lähtevän höyryn virtaus alarajahälytys
0.6	5.51.47.6	Hoyry_P_Hi	HAD01CP205_HI	BOOL	FALSE	Lähtevän höyryn paine ylärajahälytys
0.7	5.51.47.7	Hoyry_P_Lo	HAD01CP205_LO	BOOL	FALSE	Lähtevän höyryn paine alarajahälytys
1.0	5.51.48.0	Hoyry_LT_Hi	HAD01CT207_HI	BOOL	FALSE	Lähtevän höyryn lämpötila ylärajahälytys
1.1	5.51.48.1	Hoyry_LT_Lo	HAD01CT207_LO	BOOL	FALSE	Lähtevän höyryn lämpötila alarajahälytys
1.2	5.51.48.2	LV_LT_Hi	HAD01CT205_HI	BOOL	FALSE	Toisiopiirin lämpötila ylärajahälytys
1.3	5.51.48.3	LV_LT_Lo	HAD01CT205_LO	BOOL	FALSE	Toisiopiirin lämpötila alarajahälytys
1.4	5.51.48.4	Hoyry_LV_LT_Hi	HAD01CT208_HI	BOOL	FALSE	Höyryn lämpötila lämmönvaihtimen jälkeen ylärajahälytys
1.5	5.51.48.5	Hoyry_LV_LT_Lo	HAD01CT208_LO	BOOL	FALSE	Höyryn lämpötila lämmönvaihtimen jälkeen alarajahälytys
1.6	5.51.48.6	Syve_LT_Hi	LCA01CT201_HI	BOOL	FALSE	Syöttövesisäiliön lämpötila ylärajahälytys
1.7	5.51.48.7	Syve_LT_Lo	LCA01CT201_LO	BOOL	FALSE	Syöttövesisäiliön lämpötila alarajahälytys
2.0	5.51.49.0	Kylma_LT_Hi	LCA01CT204_HI	BOOL	FALSE	Kylmän jäähdytysveden lämpötila ennen hönkälaudutinta ylärajahälytys
2.1	5.51.49.1	Kylma_LT_Lo	LCA01CT204_LO	BOOL	FALSE	Kylmän jäähdytysveden lämpötila ennen hönkälaudutinta alarajahälytys
2.2	5.51.49.2	Honka_LT_Hi	LCA01CT205_HI	BOOL	FALSE	Veden lämpötila hönkälauhduttimen jälkeen ylärajahälytys
2.3	5.51.49.3	Honka_LT_Lo	LCA01CT205_LO	BOOL	FALSE	Veden lämpötila hönkälauhduttimen jälkeen alarajahälytys
2.4		vara1_Hi		BOOL	FALSE	
2.5		vara1_Lo		BOOL	FALSE	
2.6		vara2_Hi		BOOL	FALSE	
2.7		vara2_Lo		BOOL	FALSE	
5.0	5.51.50.0	Syve_P_Vika	LCA01AP101_DISTU	BOOL	FALSE	Syöttövesipumppu häiriö **(Feedpump disturbance)**
5.1	5.51.50.1	Elmo_alavesi	HAD01CL102_LO	BOOL	FALSE	kehittimen alavesiraja hälytys
5.2	5.51.50.2	Elmo_paine_luk	HAD01CP101_LOCK	BOOL	FALSE	Kehittimen höyrypaine korkea lukitsraja hälytys
5.3	5.51.50.3	Syve_ala	LCA01CL104_LO	BOOL	FALSE	syöttövesisäiliö pinta matala hälytys
5.4	5.51.50.4	Syve_yla	LCA01CL101_HI	BOOL	FALSE	Syöttövesisäiliö pinta korkea hälytys
6.0				END_STRUCT		